ACOUSTICS

FOR MUSIC STUDENTS

BY

C. SUBRAHMANYA AYYAR, B.A.,

Retired Accountant-General and formerly Member of the Board of Studies,

Indian Music, University of Madras

FOREWORD

BY

S. S. MOOPTHY RAO, B.E., F.A.Sc.,

'MUSIC IS A RATIONALISATION OF SOUND AND
A MATHEMATICS BECOME AUDIBLE'

GEORGE SANTAYANA,
'Reason in Art'

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'The One manifests itself as the Many :
The Many are absorbed in the One.'

'The drone is the Immutable Brahman
of the Vedantist's gospel.'

All this world is pervaded by Me unmanifest ;
all beings abide in Me, but I stand apart from them.

Gita - IX - 4

DEDICATED TO THE MEMORY OF

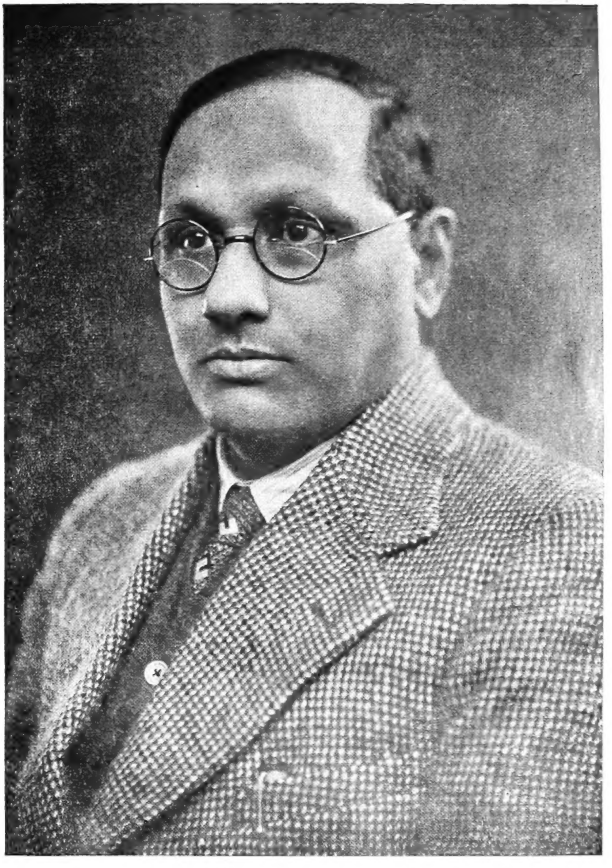
MY MUSIC TEACHER

The Late Vidwan, T. Sabhesa Iyer, (b. 1872 - d. 1948)

latterly, the First Principal of

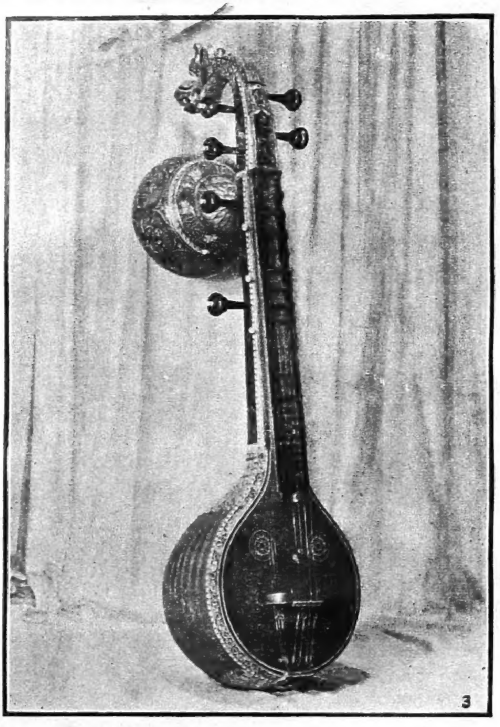
The Annamalai Music College, Chidambaram

from 1929 to 1937



Photo] AUTHOR [Wykeham, London

1. The Tambura
2. A Lady playing on the Veena



3. A vertical view of the Veena

FOREWORD

The extent to which the entertainment value of music is subjective *i. e.*, dependent on human factors varying from person to person, or objective *i. e.*, independent of personalities but depending only on physical characteristics of music, has been the theme of much enquiry and discussion among both the professionals and the critics of this fine art. Music in its sublimity has a strong appeal not only to the aesthetic appreciation of the individual but also to the emotions and can stir them to the greatest depths. In the relation between music and its effect on emotions, the sense of words, the accompanying pattern of musical tones and their associations to the particular individual are now beyond exact analysis and such effects of music can therefore be regarded as largely subjective, that is, influenced greatly by the conditioning of the subject who is listening to music. The rendering of good music also undoubtedly requires conscious, subconscious and intuitive skill on the part of the individual musician rendering the piece and to that extent is subjective. All the same, as a preliminary to good music reaching the heights of sublimity, it should have the physical acoustic characteristics necessary to produce certain specific effects in the human auditory apparatus. As an engineer, believing in the ultimate possibility of analysing and codifying in a scientific manner whatever appeals to our senses, I am one of those who consider that good music must have certain consistently definable characteristics both in its method of production and in its effect on the physical mechanism of the human ear in order that it may appeal to the generality of listeners. In other words, the emotional effect of music is largely subjective. The aesthetic effect is partly subjective and partly objective. In the asthetic rendering of music, vocal or instrumental, the border line between the definable and undefinable acoustical characteristics gets gradually shifted as we advance in our scientific knowledge of the acoustic properties of the voice and instruments producing music and of the response of human auditory mechanism to musical phrases.

Mr. C. S. Ayyar is one of those who not only believe that what is pleasing to the ear should be capable of being analysed in a scientific manner but also has been ardently practising Karnatic music on the violin for some decades and studying the rendering of music

on other instruments with a spirit of persistent enquiry. Of the two schools of Indian music, the Hindustani and Karnatic, the analysis and codification has in general been followed in a more rigorous manner in the latter school. Sri Tyagaraja is one of the greatest composers of Karnatic music. His kritis opened to Mr. C. S. Ayyar a wondrous world of sound and led him to a careful study of the musical sounds and musical graces on his violin over a number of years and have also made him publish two commendable volumes of Sri Tyagaraja's kritis in Devanagari script with full notation for the use of appropriate graces (Gamakas) in their rendering. The result of his study of musical graces have shown him that the 22 srutis with their commonly accepted definitions are inadequate for bringing forth the full aesthetic effects of Karnatic music and his views have been briefly summarised in the present book, which is bound to be of value to all those who approach music with a spirit of enquiry and analysis. I trust this book will also prove valuable to foreigners who are now taking increasing interest in Indian music. In the ultimate analysis, Mr. C. S. Ayyar has struck the key note in the statement in defining the characteristics of Indian music in the widest sense, we have to talk not of srutis in plurality but of really one sruti which is that of the Tambura. This is the background cyclic drone with which every bar, glide and burst of music produced must blend perfectly in the resultant effect on the human ear. There is no doubt that more and more scientific support will be forthcoming in future for Mr. C S. Ayyar's observations on musical graces in Karnatic music.

Bangalore,
20th August 1959

S. S. MOORTHY RAO, B. E., F. A. Sc,
Deputy Director-General of P. & T. (Retd.)
and
Ex. Member of International Frequency Registration Board, (International Telecommunication Union, Geneva)

I am grateful to Sri S. S. Moorthy Rao for his ready response to my request to write a forword to this book.

2. He is an amateur flutist, and the reader will note Sri Rao's familiarity with the scientific aspect of music.

C. SUBRAHMANYA AYYAR, B. A,
Retired Accountant General.

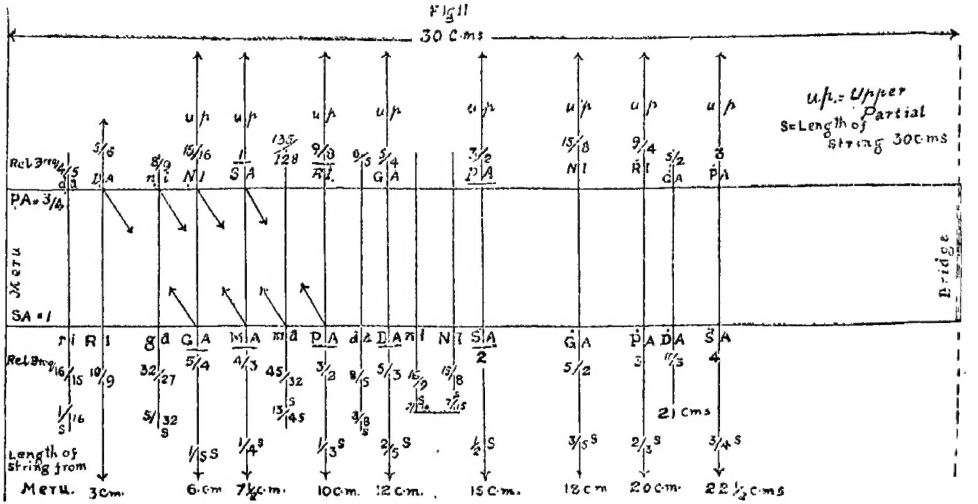


Fig 11
30 c.ms
u.p. = Upper Partial
S = Length of string 30 c.ms
Rel Brng
PA = 3/4
SA = 1
Metre
Bridge
Length of string from Metre.
30 c.ms
6 c.m
7½ c.m.
10 c.m.
12 c.m.
15 c.m.
18 c.m
20 c.m.
22½ c.ms
21 cms

ERRATA

PAGE	PARA	LINE	READ
6	...	1	Consonants
8	...	1	has
14	11.4	3	All-(Ṡa) a dot above
21	...	9	Cyclic
24	16.5	7	across
25	Table I	Col. 6	overtones
44	29.5	12	32/25
47	32.1	(1)	Kāmbhoji
65	Appendix-I	Col. 4	ri Ma da

ACOUSTICS FOR MUSIC STUDENTS

BY

C. S. AYYAR, B.A.

PREFACE

THE object of this small book is to enable students of Karnatic classical music, both vocalists, veena players and violinists to understand the scientific principles underlying musical notes (svaras) produced by them in the melodic art and it formed the subject of a lecture on 18th April, 1959 at the Central College of Karnataka Music, Madras, with a demonstration on the violin.

2. Much of the material in this book is available in the author's " The Grammar of South Indian (Karnatic) Music ", (First Edition 1939) Second Edition, practically a reprint, 1951. It was written in a diffuse and discursive manner and a spirit, challenging, (1) the statement regarding the South Indian veena in Captain C. R. Day's book "The Music and Musical Instruments of Southern India and Deccan " Page 32. (2) the theory of Indian music expounded by Fox Strangways in his " The Music of Hindostan " (1914) and repeated in his article on music in the book " The Legacy of India " (Clarendon Press, 1937) Page 311 et. seq., and referring to the author's researches in *present day* music by modern scientific methods.

3. In the author's English preface to his book " 108 Kritis of Sri Tyagaraja, Text & Notation (Sa Ri Ga Ma) in Devanagari Script with ' gamaka signs ' (1955) " the principles in his above book were explained further with reference to *gamaka* signs adopted therein for

violin technique to enable Karnatic music to be written and to be '*read*' with a fuller meaning and comprehension, than hitherto.

4. This book should interest also students of Hindustani music. Further, students of acoustics in the University classes may be able to correlate the statements in English Text books on 'Sound' and allied topics *re.* the piano, with their own Indian music, if they should possess some talent for singing, even though not specially educated in the melodic art.

5. The amazing genius of Helmholtz (1821-1894), almost a contemporary of Tyagaraja, (1767-1847) in the study of melody has really lit the true science of South Indian music. A study of this book will hush up, it is hoped, the colossal fiction of the so-called "22 Tone Indian Scale" of music.

The author has attempted to interpret the gamakas themselves in relation to frequencies of prolongable notes and their intervals. His theory of *intonation* of Karnatic music is summarised in para 40 *supra.*

	Reference Books	Abbreviations
1.	Helmholtz's " Sensations of Tone " Translation by A. J. Ellis. 1930 Fifth edition (Longmans, Green) 1st German edition 1862.	H.
2.	A. H. Fox - Strangways' " The Music of Hindostan " 1914 Oxford, Clarendon Press.	A.H.F.S.
3.	A. H. F. S's Article in " The Legacy of India " ' Music ' 1937, Oxford, Clarendon Press.	A.H.F.S. (L)
4.	Sir James Jeans's " Science and Music " 1937 Cambridge. University Press.	J.J.
5.	C. Subrahmanya Ayyar's " The Grammar of South Indian (Karnatic) Music ". Second edition, 1951. First edition, 1939.	G.M.
6.	G. H. Ranade's " Hindusthani Music " Second edition, 1951.	H.M.
7.	H. Lowery's " A Guide to Musical Acoustics " (Dennis Dobson, London).	M.A.
8.	H. Lowery's " The Background of Music " Hutchinson.	B.M.

CONTENTS

CHAPTER - I.

6. Definitions.

6.1 **Acoustics** - The science of sound, as studied by a physicist with reference to a single sound and all that goes in its production by the human voice or stringed, wind and in percussion instruments (Nāda Sastra).

6.2 **A Musical Note** - (Svara). It has three qualities.

(1) Pitch - *Sruti*, high or low, (2) loudness or intensity, (3) timbre, by which the human ear distinguishes what instrument generates the note, say a violin, veena, nādasvara, gotu vādyam, flute, clarinet, etc., etc.

6.3 **Tone** - A simple tone is produced by the tuning fork. It has a single frequency.

A complex tone is made up of a fundamental pitch and a few harmonics (over tones) *anunadam* or 'Svayambhu' svaras, as emitted by a violin string etc.

N. B. The bamboo flute gives out practically a simple tone for each note, except for a faint octave, through each note may be played in a higher or lower *octave* (sthayi) by altering the pressure of the blown air.

6.4 **Music** - Music lies in vowel sounds only. They belong to the class of sustained notes; the consonants are just brief and transient noises (H). Music does not consist of single or discontinuous notes only. Melody weaves itself into the pattern of a chain or plaited hair. The acme of production on instruments, of melodic music, is that it should approximate to the nuances and graces of human voice.

6.5 **Sruti** - In the singular number, though originally meaning the Vedas, it is used in music with reference to the *drone* of the

Tambura, which as four strings for twanging-*vide* plate No. 1 and is a constant accompaniment in the present day melodic art, with which the voice or the instrument must be consonant.

N. B. It is used in the plural number for microtonal changes, in the ancient Indian music theory of Srutis, with reference to the 12 svaras denominated on the veena frets to the octave (sthayi).

6.6 **Scale concept & Raga concept**. Scale concept is just the skeleton frame work, giving the svaras used in ascent and descent. Raga concept is the art form of the melody with its special features, gamakas (movements), anusvaras (crushed notes), before and after each svara.

6.7 Raga (melody type) is a unique conception in Indian melodic art - both in Hindustani and Karnatic. Regarding Karnatic Music, since the days of Tulaja of Tanjore (1783 A. D.) *ragas* have been described by the names of the twelve swaras arising from the frets of the veena in an octave, and worked into the structure under the several Mela (parent) and Janya (derivative) ragas, according to the svaras chosen. The run of the phrases in specified ragas for which alapana (elaboration) could be realised, had been given therein. The process of writing down the run of the phrases had been continued in (i) Palamaneri Swaminatha Iyer's "Ragavibhodini" (1901) in Tamil for 89 ragas and (2) Thatchuru Srirangarachari's " Gayaka-siddhanjanam" Second Part (1905) in Telugu for 60 ragas very elaborately. Similarly, Subbarama Dikshitar in his magnum opus (1904) has given raga phrases with *gamaka signs* to denote the *intonation* - an important feature in the art of melodic music.

7. **General observations.**

7.1. South Indian classical music is a very high melodic art and requires deep study and practice. In olden days this classical

music was taught individually to students by a teacher, and here the student must evince certain mental attitudes in regard to this learning. Firstly, a zeal to absorb the knowledge of the teacher, (2) to question the latter in regard to his doubts ; (3) a self-questioning (pariprasnā) as to whether he (the student) has learnt correctly the pitches and the graces, in the melody taught ; and (4) to listen to melodies sung by others, whether the same or similar compositions in the same or different *ragas*, with an attention to absorb fresh ideas or movements, if any.

7.2 Music students who may benefit by reading this book should know what svaras are - i. e. they should have *svara gnana* and can define and recognise the svaras in relation to the *ādhara* sruti or shadja or the fundamental chosen. In the melodic music of India, every singer *today* chooses his fundamental pitch for the melody, which should not change in the exposition of the raga or melodic pieces. It is connected with the musical compass of his voice, which has a range of, say, 2 to 2½ octaves. The tambura is adjusted to his fundamental pitch and it is essential that he should sing, if he is a vocalist, to its accompaniment so that the ear will correct the human voice, if it is dissonant ; and he must be particular to watch and correct the dissonance. He must also know and be familiar with the veena, South Indian national instrument, depicted in the picture of Sarasvati by Ravi Varma, *vide* plate 2 and he must be conversant with the names of the svaras as commonly denominated for the notes on 12 frets. These 12 frets have been placed in hard wax, to each octave or (Sthayi) under each of the four playing strings, across the *dandi* and 24 frets in the 2 octaves, by a method of trial and error, *vide* para 14 *supra*.

8. Names of svaras or notes :

8.1 The svaras are only seven all the world over. The words Shadja, Rishabha, Gāndhāra, Madhyama, Panchama, Dhaivata

and Nishāda are extant from the days of Panini, the grammarian. They are abbreviated in svara singing or writing music, as Sa Ri Ga Ma Pa Da Ni; (The Da is purposely unaspirated, for reasons which will be stated later, when we come to veena fretting.) In Western music, they are denominated C D E F G A B with *qualifications* as for the Sanskrit words, or letters. They can be denominated as the fundamental or tonic, for Shadja; and as for the others, Ri can be called the second, Ga the third, Ma is the fourth, Pa the fifth, (as the Sanskrit word also gives the same meaning), Da the Sixth, and Ni the seventh. The higher Shadja or Ċ is called the Octave. For purpose of *clarity*, as there are only 12 frets on the veena or 12 keys on the piano, to the octave, we can use the small and big letters in their nomenclature.

8.2 We shall write down with capital letters C D E F G A B C for the *diatonic* scale, alike Sankarābharana of South India, and d, e, f, a and b for the other five notes. For the Indian notation, the 12 notes in their order will be written as Sa, ri, Ri, ga, Ga, Ma, ma, Pa, da, Da, ni. Ni and Ṡa (the octave.) Subbarama Dikshitar in his *magnum opus* "Sangeeta Sampradāya Pradarsini" has used no signs against the Telugu letters for the Sankarābharana scale; for reasons thereof, *vide* para 17 *supra*.

N. B —A dot above a svara denotes the higher octave; a dot below a svara denotes one of a lower octave.

CHAPTER - II.

9. **Relative Frequency or pitch.**

9.1 " Long before anything was known of pitch numbers, or the means of counting them, Pythagoras had discovered that if a string the divided into two parts by a bridge, in such a way as to give two constant musical tones when struck, the lengths of these parts must be in the ratio of these whole numbers. If the bridge is so placed that 2/3rds of the string lie to the right, and 1/3rd on the left, so that the two lengths are in ratio of 2:1, they produce the interval of an Octave, the greater length giving the deeper tone. Placing the bridge so that 3/5ths of the string lie on the right, and 2/5ths on the left, the ratio of the two lengths is 3:2, and the interval is a fifth.

9.2 " These measurements had been executed with great precision by the Greek musicians, and had given rise to a system of tones, contrived with considerable art. For these measurements, they used a peculiar instrument, the *monochord*, consisting of a sounding board and box, on which a single string was stretched with a scale below, so as to set the bridge correctly (*i. e.* as in the modern sonometer). " (Helmholtz)

9.3 "The vibrational values of the notes were worked out, however very late in the 17th century, by means of, what is called, a Siren. It is just a thin disc of card board or thin plate, which can be set in rapid rotation about its axis by means of a string which passes over a larger wheel. On the margin of the disc, there is punched a set of holes at equal intervals. These holes may number 16 at the top most circle, that is nearest the edge, and in smaller concentric circles they may be reduced to 12, 10 and 8 respectively in each circle. But the holes must lie equidistant along each circle. If air is blown through a tube

along each circle, notes are produced and the relative pitches can be determined from the note arising from each set of holes, by the ear.

9.4 " Hence it follows firstly that the pitch of a tone depends only on the *number* of puffs or swings, and not on their form, intensity or method of production. Further, it is very easily seen with this instrument that on increasing the velocity of rotation and consequently the number of puffs produced in a second, the pitch becomes sharper or higher. The same result ensues if, maintaining a uniform velocity of rotation, we first blow into a series with a smaller and then into a series with a greater number of holes. The latter gives the sharper or higher pitch.

9.5 "The series of 16 holes gives the Octave of the series of 8 holes and the Fourth, of the series of 12 holes. The series of 12 holes gives the Fifth of the series of 8 holes, and the minor Third of the series of 10 holes. While the series of 10 holes gives the major Third of the series of 8 holes. The four series consequently give the constituent musical tones of a major chord.

9.6 "By these and similar experiments we find the following relations of the pitch numbers :—

	(Remarks by the Author)
1 : 2 Octave	Sa : Sa
2 : 3 Fifth	Sa : Pa
3 : 4 Fourth	Sa : Ma
4 : 5 Major Third	Sa : Ga
5 : 6 Minor Third	Sa : ga

9.7 "When the fundamental tone of a given interval is taken an Octave higher, the interval is said to be *inverted*. Thus a Fourth is an inverted Fifth, a minor Sixth an inverted major Third, and a major sixth an inverted minor Third. The corresponding ratios of the pitch numbers are consequently obtained by doubling the smaller number in the original interval.

From 2 : 3 the Fifth, we thus have 3 : 4 the Fourth
From 4 : 5 the major Third 5 : 8 the minor Sixth
From 5 : 6 the minor Third, 6 :10=3 : 5 the major Sixth

Author's Remarks

Ma to Sa = 4/3	Sa to Ma =3/2 R. F.
da to Sa = 8/5	Sa to da =5/4 R. F.
Da to Sa = 5/3	Sa to Da =6/5 R. F.

9.8 " These are all the consonant intervals which lie within the compass of an Octave. With the exception of the minor sixth, which is really the most imperfect of the above consonances, the ratios of their vibrational numbers are all expressed by means of the whole numbers, 1, 2, 3, 4, 5, 6. " (Helmholtz)

10.1 From this, the reader can associate the Western terms used with the South Indian terms now used for the same svaras. Fifth is Panchama; Fourth is Suddha Madhyama; Major Third is Antara Gāndhara (though I would refer the word Antar*gata* Gāndhara as it merges with Sa and Pa); the minor third is Sādharna Gāndhara (though that particular frequency will *not* be found on the shadja string of the veena).

10.2 The minor sixth is Suddha Dhaivata according to South Indian nomenclature. The Major Sixth is the Trisruti Dhaivata, which is the note found on the Shadja string of the veena where the overtone can be heard. The Chatusruti Da, as it is usually denominated, is a misnomer. The above will be clear when we describe veena fretting, *vide* figure 11.

11. **Manner of approach to svaras.**

11.1 We shall now consider the manner of approach to the svaras of Sankarābharana, that is, how the voice or instrument can most easily produce them and which we can *prolong* straight *without* any quiver or grace, when the drone of the Tambura, is heard. There is a background note for every svara pronounced, to my knowledge, and without catching the Sa/Pa of the drone we cannot reach them correctly.

11.2 Sa. We either say Sa direct or Sa below, or again the voice may taken up (lower) Sa and come up to Sa; or it takes (lower) Pa and goes to Sa in a slide.

11.3 If we want the chatusruti Ri (9/8) the voice gets to the Pa of the drone and comes to Chatursruti Ri, rising a Pa interval. Similarly, Ga is (Sa) Ga; Ma is (Sa) Ma: Pa is (Sa) Pa ; Da (Trisruti) can be produced either **direct** or better still, it is/Sa Da / ; and in actual pay occasionally, the Da is played on Pa string along with the Sa behind, of the violin.

11.4 Ni is really (Pa) Ni if one wants to produce the harmonic Ni; and higher Sa is (Pa) Ṡa, or (Sa) Ṡa. As we go up they are (Pa) Ṙi; (Pa) Ġa or (Sa) Ġa; (Sa) Ṁa; (Sa) Ṗa.

N. B. The svaras in brackets form really the background, of the svaras to be reached.

11.5 Anuswaras (crushed notes) as above, occur both behind and also in front.

EXAMPLES :

I.

(Pa) \		/ Ṡa \		
Ma	Pa	Da	Pa	} Kriti in Kedaragaula of Ramnad Srinivasa Iyengar, Svaras above line are anuswaras.
Sa	ra	gu	na	

II.

/ Ṡa \			W	
Pa da	Pa ,, da		Ma Pa	} Mayamalava gaula, Kriti of Tyagaraja Tulasidala (Charana).
Sa ra	see		ru ha	

CHAPTER III

12. Helmholtz's Study of Melody.

12.1 Major and Minor Chords.

The European has apparently worked out the natural notes on the basis of coalescing three notes struck at a time, major chord (1, 5/4 and 3/2) and minor chord (1, 6/5 & 3/2) from Shadja (R.F.1), Panchama (R.F. 3/2) and Suddha Madhyama (R.F.4/3) respectively. The three major chords will give the frequencies (1, 5/4 and 3/2) and (3/2, 15/8 and 9/4) and (4/3, 5/3 and 2). The three minor chords have the frequencies (1, 6/5 and 3/2) and (3/2, 9/5 and 9/4) and (4/3, 8/5 and 2).

12.2 That is, the svaras obtained in the order of ascent within the octave or one sthayi are Shadja, Chatursruti Rishabha, Sadhārana Gāndhāra, Antargata Gāndhāra, Suddha Madhyama, Panchama. Suddha Dhaivata, Trisruti Dhaivata, Kaisiki Nishāda, Kākali Nishāda, and Higher shadja, the frequencies being, 1, 9/8, 6/5, 5/4, 4/3, 3/2, 8/5, 5/3, 9/5, 15/8 and 2 (the octave). One will notice in this enumeration, the suddha rishabha (R.F. 16/15) and a pratimadhyama or *sharpened* fourth are missing. These, including the last two, make all the 12 notes. H has also included *true notes R. F. 7/4 and R. F. 10/9*, vide his harmonical chart, vide para 13 *supra*.

12.3 We have explained in paras 9 and 10 in H's own words the meaning of Relative Frequencies and vibrational values of the several musical notes which we come across melodies, and in para 11, the manner of our approach to the svaras of the Sankarābharana or the major diatonic scale.

13. Scale of the harmonical

Given below is the scale of the harmonical from H's page 17, constructed for him. We will detail only the notes of a Single Octave, and they are clearly prolongable and sweet, as the instrument is described therein.

13.2

Notes.	RATIOS		CENTS		Remarks
	Note to Note (Intervals)	Note to C (R. F.)	Note to Note (interval in cents)	C to Note (in cents)	
(1)	(2)	(3)	(4)	(5)	(6)
C	—	1	—	○	
	9 : 10		182		
D_1	—	10/9	—	182	**
	80 : 81		22		
D	—	9/8	—	204	
	15 : 16		112		
E^1b	—	6/5	—	316	
	24 : 25		70		
E_1	—	5/4	—	386	
	15 : 16		112		
F	—	4/3	—	498	
	8 : 9		204		
G	—	3/2	—	702	
	15 : 16		112		
A^1b	—	8/5	—	814	
	24 : 25		70		
A_1	—	5/3	—	884	
	20 : 21		85		
7^Bb	—	7/4	—	969	
	35 : 36		49		
B^1b	—	9/5	—	1018	
	24 : 25		70		
B_1	—	15/8	—	1088	
	15 : 16		112		
Ċ	—	2	—	1200	

** This is the note on the 2nd fret placed on the shadja string of the veena. What a wonder!

13.3 Please see paras 9 and 10 for names of the svaras. The reader should note that H has left out the semitone (ri) (R. F. 16/15) and the note of sharpened fourth (ma) among the notes in the harmonical, though the R. F. 16/15 appears four times as an interval between certain notes, as given below.

(a) $E_{\,1}$ (R. F. 5/4) and F (R. F. 4/3) *i. e.* Ga (Antargata Gandhara)* and Ma (Suddha Madhyama) ;

(b) $B_{\,1}$ (R. F. 15/8) and $\dot{C}$ (R. F. 2)

(c) $A^{\,1}{}_{b}$ (R. F. 8/5) and G (R. F. 3/2).

(d) D (R. F. 9/8) and $E^{\,1}{}_{b}$ (R. F. 6/5).

*The reason being that the natural note of the human voice Ga is alittle sharper than R. F. 5/4. In the latter case, the voice has to be fully opened and Sa has to be remembered. See para 36 *supra*.

13.4 We shall deal shortly with R. F. 7/4 denominated as $^{7}B_{b}$ and with R. F. 10/9.

13.5 Frequencies *not* considered concordant with the drone by H.

Svara	Cyclic cents.	Relative frequency	Name	South Indian name	Remarks
ga	294	32/27	Pythagorean minor third.		We can realise the observations in para 13.5 from the very signs of the
Ga	408	81/64	Pythagorean major third.		

Svara	Cyclic cents.	Relative frequency	Name	South Indian name	Remarks
da	792	128/81	Pythagorean minor sixth.		svaras given in the harmonical chart, vide explanation at para 25.4 to understand the said signs.
Da	906	27/16	Pythagorean major sixth.		
ni	996	16/9	Pythagorean minor seventh.		do
Ni	1110	243/128	Pythagorean major seventh.		do
ma	520	27/20	Acute fourth.		For similar reasons we classify these two as discordant with the drone.
	610	64/45	Diminished fifth.		

CHAPTER - IV.

14. Veena Fretting

14.1 We have to examine the notes obtainable on the veena properly fretted and the strings tuned. See para 18.1 The strings are tuned Sa Pa Sa Pa. At 8 of the frets on Shadja (open string) next to the player, *vide* figure 11, we hear upper partials in the two octaves. They are obtainable at the lightly damped positions of a half, a third, a fourth. a fifth, and two fifths in the first Octave, calculating from the Meru ; and beyond the octave, at three fifths, two thirds and three fourths, in the second octave ; *i. e.*, the veena has been fretted by listening to the upper partials or

Swayambhu svaras at the following notes on Sa string when lightly touched but *not* pressed; higher shadja, panchama, suddha madhyama, antargata gandhara, Trisruti Daivata, antargata Gandhara higher, Panchama Higher and Tara Shadja. On the violin with strong light in the very first octave, one can observe, with one's eyes when powerfully bowed on the silver string, two loops at higher Shadja, three loops at Panchama, four loops at Suddha Madhyama, five loops at Antargata Gandara and five loops at trisruti dhaivata; and even at the other three positions higher than the octave, we can listen to the harmonics as on the veena itself; the playing strings are tuned Sa Pa Ṡa Pa on veena.

14.2 If you look at the plate of the Veena fretting, vide plate 11, the veena frets have the frequencies on the Shadja string as below.

Sa (the open string)	ri,	Ri	ga	Ga
1	16/15	10/9	32/27	5/4

Ma	ma	Pa	da	Da	ni	Ni	and	Ṡa
4/3	45/32	3/2	8/5	5/3	16/9	15/8		2

14.3 If one just evaluates, what the notes would be on the **Pa** string, of the veena, which is lower than the Shadja, one will find them to the following R. Fs.

	Pa	da	Da	ni	Ni	Ṡa	ri	Ri
1/2 of	(3/2,	8/5,	5/8,	16/9,	15/8,	2)	135/128	9/8

ga	Ga	Ma	ma	Pa
6/5,	5/4,	4/3,	45/32,	3/2

so that even among the frets (which compare with ri Ri ga) with values of 135/128, 9/8, and 6/5, it is seen they do *not* tally with ri, Ri, Ga, of values 16/15, 10/9 and 32/27 placed on the Sa String, *vide* page 28 of G. M. second edition.

14.4 The reader may enquire how it is that the relative frequency 10/9 (Ri) has been put in at the second fret on the Shadja

string. The fact is that frequency of Ri $_1$ (10/9) is on Sa-Ma relationship with the svara Da of (R. F. 1/2 x 5/3) on the Panchama string, behind the Shadja string. Being at an aliquot part of the string, it is a sweet note.

14.5 Further, it is a minor third (6/5) interval from Suddha Madhyama (R. F. 4/3) on the Sa string. Again the South Indian is used to it, as evinced by the song 'Darini-Telusu Konti' in the Suddha Saveri raga of Tyagaraja with the svaras.

Ṡa, – Da, – Pa, – Ma, Ri, – Sa, – etc.,
Daa ri ni Te lu su

Just as there is a step-down from svara Ṡa to svara Da (interval being 6/5) there is a similar step-down from Ma to Ri$_1$ (R. F. 10/9) with the same minor third drop. Likewise in Mohana Sa Ri$_1$ Ga Pa Da Ṡa, especialy in *Alankaras*.
1 10/9 5/4 3/2 5/3 2

The reader will also notice from the veena fretting that this Ri$_1$ is a comma (R. F. 81/80) lower than Ri (on the Panchama string) of the pitch R. F. 9/8.

14.6 The problem of fretting of the veena and of placing of the keys of the piano is alike. The South Indian *escaped* the *equal temperament* of the piano by placing 8 of the notes by listening to upper partials *vide figure* 11. That is to say, we measured, in a musical sense, the lengths, for the various notes, by listening to musical sound, and *not* by actual measurement.

15. A. H. F. S. Review of G. M. First Edition

15.1 Mr. F. S. in his review in "Music & Letters", London, January, 1940, has caught this view point, which is quoted below :

" .. The European, wedded for sufficient reason to equal temperament, has not forgotten that he had, three centuries ago, pure intonation, and he can therefore understand the Indian scale, though he may be unable to feel it.

" Both scales fill an octave with twelve semitones of different sizes and both therefore have a comma (the quotient of the major and minor tones) to negotiate. The crux is in the first three notes-in the C-scale, D_b, $D_\square$, E_b.

(Given in Cycle cents)

	C	D	$D_\square$	E_b
EUROPE	0	*112*	*204*	316
INDIA	0	112	182	294 C-string
	0	92	*204*	316 G-string

" The numbers italicized show our intervals 16/15, 9/8, 6/5 and are correct, and they recur on one or other of the Indian strings. But of the *consonances*, these make three of ours false - B_b - D, D-A, E_b - B_b; while in the Indian C-string B - D, D - F $\S$, G – D, E_b — G, and on the G-string B_b - D, D_b - F, D_b - A_b, D - A, E_b - B_b are false. Thus on one or other string, but not on both, the Indian can get all his consonances true, whereas on our keyboard there are three that are always false; our strings create no problem, of course, because they are not fretted ".

15.2 *N. B.* The reader is perhaps now convinced that the veena is *not* fretted *i. e.* - "tuned" - to equal temperament, as stated by Captain C. R. Day in his book " The Music and Musical Instruments of Southern India and Deccan" at

page 32, and this error was pointed out even in the first edition of the author's book G. M. at page 76-A. It is with regret that the author notes that a similar error has been committed by Mr. K. P. Viswanatham of the Annamalai University in his *Sangeeta Oli Nool* (1936) Tamil at page 103.

15.3 Reference must also be made to the footnote at page 311 of A. H. F. S. article on music in the "Legacy of India" (Clarendon Press, 1937) "that the Indian considers A + , whereas we (the Westerners) consider, A to be the natural note." This observation of his can only apply to Hindustani music, and that he has correctly understood that the South Indian thinks alike the European, is proved by the veena fret of Major Sixth, and his review above.

15.4 The remarks in the review regarding the consonance of svaras on the two strings, Shadja and Panchama may be transliterated thus :

On the *Sa* string, the notes in	Ni & Ri
the margin, as placed in the	Ri & ma
veena, are *not* consonant, while	Pa & Ri
they are so on *Pa* string.	ga & Pa

On the Pa string, the notes in	ni & Ri
margin, as placed on the veena,	ri & Ma
are *not* consonant, while they	ri & da
are so on the Sa string.	Ri & Da
	ga & ni

But Mr. A. H. F. S. has gone off *at a tangent*. We are not really concerned with the above observation.

16. **The problem of microtonal changes & concordance with the drone.**

16.1 Our problem is what the microtonal changes are which take place in gamakas when we play a melody by pulling across the veena frets. It must not be forgotten that the two *ends* of the gamakas, i.e. their frequencies, *must be consonant with drone*. of the tambura, plate 1, or the twanging three strings below on the veena intended for rhythm, (serving also as a drone), tuned Sa Pa Ṡa.

16.2 The crying need of the day is the musicians should know what the *prolongable* notes are, in the Octave; and their places; and not simply dabble with gamakas.

16.3 Having carefully observed on several occasions from 1938, the veena fretting (even sitting with the tuner for 8 hours during the entire work), the author was *exercised* by certain facts he had noticed. On the Pa string against frets Ma and Pa, the svaras ni Ṡa are noticeable on Shadja string, We have no doubts about Ma, Pa and Ṡa at all Even the Ma on the Pa string is carefully placed by tuning the (rhythm) strings as Sa Ma and Ṡa. Therefore, the ni on Sa string is clearly R. F. 16/9 for it has a 9/8 drop from 2.

16.4 *N. B.* In the play of melody on the veena, one can notice that that fret which produces ni, is always pulled across and is raised in pitch. So is the similar pulling across the frets ga and ma on the Shadja string during play. That is to say, that the notes (ga, ma and ni) produced at these three frets are *not* consonant with the drone. Pa to ma. interval on the

veena is R. F. 16/15 *vide* figure 11, *i.e.* Sa, R. F. 2 to Ni, R. F. 15/8.

16.5 **Frets not concordant with the drone.**

According to the ancient theory of the 22 intervals in the Octave, *Srutis* as they are commonly called, which musicologist allege recently that these intervals have been worked out on the Sa - Pa & Sa - Ma bases, and when we find that 3 of the notes on frets of the Shadja string itself on Sa - Ma bases are not consonant with the drone, without pulling the string acros those frets in melody, the said theory must be considered *partially incorrect*, to say the least. More of this subject later, when the frequencies worked out by Fox Strangways and others, para 26.2 and 29.4 are discussed : —

$1 \times 4/3 =$ R. F. $4/3$ $\qquad$ $4/3 \times 4/3 =$ R F. $16/9$

$1/2$ of $16/9 \times 4/3 =$ R. F. $32/27$

CHAPTER - V.

17. **Relatives Frequencies** and aliquot parts of playing strings.

17.1 The term relative frequency should now be clear to the reader. If the Shadja is denominated by R. F. 1. the relative frequencies of others are the inverse of the vibrating length of the string against the whole, the tension being kept constant. They can best be remembered and understood as relating to aliquot parts of the string *damped*.

TABLE - I FOR SHADJA STRING

	Distance from Meru the head	Length vibra-ting	R. F	Note or Svara (South Indian)	English name.	Ref. to ov r-tones by light touch.	Remarks.
—	Nil	Whole	1	Shadja	Tonic	—	
	1/2	1/2	2	Higher Sa	The Octave	2 R. F.	
	1/3	2/3	3/2	Panchama	Fifth	3 R. F.	
	1/4	3/4	4/3	Suddha Madhyama	True Fourth	4 R. F.	
A	1/5	4/5	5/4	Antargata Gāndhāra	Major Third	5 R. F.	
	1/6	5/6	6/5	Sadharana Gāndhāra **	Minor Third	6 R.F.	Overtone heard on 'G' Violin String.**
	2/5	3/5	5/3	Trisruti Dhaivata***	Major Sixth	5 R. F.	***
B	1/7	6/7	7/6	...	Septimal Minor Third	H	Pages 187 & 212
	1/8	7/8	8/7	...	Super Second		H. See P. 187 & para 30.1
	1/9	8/9	9/8	Chatusruti Rishaba @	Diatonic second		Major tone from Shadja@
C	1/10	9/10	10/9	Trisruti Rishabha	Minor tone (Grave second)		Diatonic second reduced by a 'comma' @@
	1/16	15/16	16/15	Suddha Rishabha	Just semitone		112 cyclic cents.

	Distance from Meru the head	Length vibrating	R.F	Note or Svara (South Indian)	English Name.	Ref. to over-tones by light touch.	Remarks.
D		1/21	20/21	21/20	Sub Minor Second		H. Page 17 85 cyclic cents
		1/25	24/25	25/24 (5/4 ÷ 6/5)	Small Semi Tone 70 cyclic cents		H Page 17
		36/35 The ratio of 6/5 to 7/6.			or of 9/5 to 7/4 in Table II		H Page 17 49 cyclic cents

17.2 **Explanations for Table I.**

** Will be found on the Panchama string on the veena.

*** The prolonged note Da of Kāmboji raga.

@ Will be found on the Panchama string on the veena.

@@ The second fret on the Shadja string. A Comma is 22 cyclic cents.

General observations :-

The Indian can recognise the svaras in Blocks A and C.

16/15 : 25/24 : 128/125 being the difference
(112 cents) (70 cents) (42 cents) between 1st and 2nd item.
(semitone) (small semitone) (Diesis)

R. Fs. 10/9, 9/8, 6/5, 5/4, 4/3, 3/2, 5/3, are stated to be True prolongable Notes by H page 17 (vide para 13.2)

17.3 The veena cannot be used for measurement of lengths vibrating, as the bridge is curved at the top, and owing to the sloping Dandi, the exact point of contact cannot be determined.

17.4 The European has the names major tone, minor tone, and semitone, for certain intervals. The major tone is the interval from Panchama (R. F. 3/2) to Suddha Madhyama (R. F. 4/3) i. e. R. F. 9/8 obtained by division. The minor tone is the interval from the major sixth (R.F. 5/3) to Panchama (R. F. 3/2) i. e. R. F. 10/9. The semitone is the interval from the Suddha Madhyama (R. F. 4/3) to the major third (R. F. 5/4) i.e. R. F. 16/15. The semitone may be denominated as Dvisruti.

18. **Table II for Panchama String.**

18.1 On the veena, Panchama is tuned in the lower octave and is behind the Shadja string, vide plate 2. Its R. F., therefore, is 1/2 x 3/2 or 3/4.

18.2 The relative frequencies will be given in the table below, in relation to Panchama R. F. 3/2, so that they may be taken as in relation to the violin string tuned Pa, next to Sa, and not in the reverse order, as in the veena.

	Distance from Meru (the head nut)	Length vibrating	R. F.	Note or Svara (South Indian)	English name.	Remarks.
A	Nil	Whole	3/2	Panchama	Just Fifth or Dominant	
	1/2	1/2	3	Higher Panchama		
	1/3	2/3	9/4	Higher Chatusruti Rishaba	Higher Diatonic second	
	1/4	3/4	2	Higher Shadja	Octave	

	Distance from Meru (the head nut)	Length vibrating	R.F	Note or Svara (South Indian)	English name	Remarks.
A	1/5	4/5	15/8	Kakali Nishāda	Just major seventh	
	1/6	5/6	9/5	Kaisiki nishāda	Minor seventh (acute)	Not found on Shadja string
	2/5	3/5	5/2	Higher Antargata Gandhara	Higher major third	
B	1/7	6/7	7/4	...	Septimal (seventh *minor harmonic* seventh natural)	H Page 17
	1/8	7/8	12/7	...	Super major sixth	H Page 456 addition by Ellis.
C	1/9	8/9	27/16	Chatusruti Dhaivata	27th harmonic (Pythagorean major sixth)	
	1/10	9/10	5/3	Trisruti Dhaivata	Just major sixth	
	1/16	15/16	8/5	Suddha Dhaivata	Just minor sixth.	
D	1/21	20/21	21/20			
	1/25	24/25	25/16		25th Harmonic	2 major thirds up from Sa i.e. 5/4 x 5/4

The Indian can recognise the svaras in Blocks A & C.

18.3 R. Fs. 3/2, 9/8, 2, 15/8, 9/5, 5/3 and 5/4 have been stated to be true prolongable Notes by H page 17 (vide para 13.2).

CHAPTER - VI.

19. Septimal minor seventh.

19.1 In the author's early lessons in 1919 from his teacher and in the song ' Sarva Bhowma Saketa ' of Tyagaraja (in Raga Panjaram). the short ni is repeated so often, as can be seen from the passages below; and it can be noticed to be a definite sweet note, especially in the play on the violin, *without* any gamaka or movement, and the bow is changed in direction, to produce the effect of consonants.

(1) ni ni *ni Da Da,* Da / Ṡa ; Ṡa *ni* Pa-Da Ṡa ni-Pa Ma Pa
Sa rva Bhau ma / Sa ke ta Ra ma ma na

(2) ;,- ṇi ṇi ṇi, ṇi / *ni Da Da,* , *Sa Ri Ma Ri* Ma, Ma
Sa ra bal ka ra da . de va

19.2 It will be understood that the first ni's are lower than 16/9 R. F. in line .1 as they are true notes at the commencement of the song. They are played *without* any gamaka on the violin. The first three ni's are R. F. 7/4 and the ni in *Sa ni* Pa is 9/5 R. F. Italics of svaras indicates half time.

19.3 If we play Sa Ri Ga Ma from suddha madhyama as fundamental on the G string, without changing the South Indian tuning of the strings, the fact R. F. 16/9, Ma of Ma, is different from R. F. 7/4 can be recognised. When playing the above, the South Indian will not touch the open string Pa, but will play the Ri on the Shadja string by going up from the original Ma by a slide, because he is generally used R_1 to 10/9 R. F., interval from Shadja.

19.4 The note of R. F. 7/4 has been mentioned by H as a true and prolongable note (svara) vide para 13.2. The author, however, would make sure, that 7/4 R. F. is the correct note, coalesing with the drone, only after hearing the upper partial 7, just as we hear the upper partial 5 at Da and Ga (Major Sixth and Major Third) respectively on the violin, by a light touch at those points. This note R. F. 7 can be heard with a light touch in the Pratimadhyama (ma) region of the violin, on the Silver G string, at 2/7ths from the nut of the violin. There is no other way of *realising* the correct pitch of R. F. 7/4. This point was noticed by the author earlier than the year 1939. Let the violin player assure himself of what the author has said above.

19.5 The *prolonged* note in 7/4 R. F. can be heard in Surati raga also, which is its special feature, in the phrase.

Ri Ma - Pa - *Sa ni* ni, Da Pa (the prolonged ni)

20. **Septimal Minor Third.**

20.1 The relation between Pa (R. F. 3/2) and ni (R. F. 7/4) is R. F. 7/6; denominated septimal or subminor third, H page 212. It is the on corresponding position on the Shadja string from Sa. And is the note R. F. 7/5 where we heard the partial 7, also used in our music? (Regarding R. F. 7/6 see my research paper - para 22.)

20.2 The septimal minor third ga (R. F. 7/6) is heard in the Ananda Bhairavi raga in the phrase *Sa ga* ga, Ri Sa / ee ja . va . mu in the prolonged ga of O' Jagadamba in the kriti of Syama Sastri, and in the phrase Ri Ma ga Sa when we play that raga. These ga's are played without any gamakas on the violin in the instances mentioned.

20.3 Another example of Ananda Bhairavi from a pada (the second ga long is R. F 7/6)

; ; Sa, / Ri ga *ga*; Ri / Sa ni, /
ma n chi di na – mu

20.4 The fixation of minor sixth (R. F. 8/5) (da).

For this fixation on the Veena, the tala or the drone strings of the veena were tuned Sa Ma Ṡa and the minor chord Ma da and Ṡa was twanged together, to get the consonance in question. Mention is made of this fact particularly, for thought, when the semitone interval will be discussed in para 27, (See para 16.1 in this connection re the drone, in the veena.)

20.5 The beauty of fretting of the South Indian veena by the methods adopted in Tanjore lies in the fact that frequency intervals of 5/4, 4/3, 3/2, 5/3 and 2 are obtainable from the svaras Shadja (R F. 1.), Panchama (R. F. 3/2) and Suddha Madhyama (R. F. 4/3) (True Fourth).

21. **True notes not found on the frets of Shadja string** of the veena.

21.1 The R. Fs. 6/5 and 9/5 were mentioned in Tables I and II paras 17.1 and 18.2 though referred to as prolongable notes, in H page 17, mentioned in para 13 2. They, as prolongable notes, are connected with the *Ritigowla raga* and notation is given below, for two examples from the melody 'Janani ninuvina' of Subbaraya Sastri.

Ex. 1. ṇi ṇi, Sa, ṇi , - The first ni is R. F. 7/4 and the *second.* ni prolonged is played on the Pa string and is clearly R. F. 9/5. It is very resonant on the Panchama violin string.
Ja na ni .

w
Ex. 2. ṇi Sa-ga ga- Ma, Ma-The *second* ga will be found as R. F. 6/5 and will be noticed as sharper than those in the raga Ananda Bhairavi.
Vi ni ni nu tsa la

22. **Septimal svaras or notes.**

We have already alluded to R. F. 7/4 natural seventh harmonic, H Page 17, and R. F. 7/6 septimal or subminor third and given examples where they are used in melody, vide paras 19.1, 19.2 and 20.2, 20.3 respectively. R.F. 7/6 has been proved, from oscillograph curves to exist in our melody vide 'Current Science' of Bangalore, No. 2, February, 1953, page 39 – 40. R. F. 7/5 septimal or sub-minor fifth is in all probability used in our music. This svara is particularly noticeable with a resonance when one ends with the note (ma), in Vachaspati raga, as in the phrase Pa Da ni Da - Da Pa Pa ma. The author has not noticed such a resonance in ma's of other ragas. An example is given below, from Patnam Subramanya Ayyar's kriti " Ennadu nee kripa " vide *charana* Kanna - Thandri Napai Karuninchu / ma ma against the words ma ni. Aroha is Sa Ri Ga ma Pa Da ni Sa and Avaroha is the same.

; Pa Pa, Da *Da Pa / Pa Da ni Da* ni - *Da ni / Sa ni ni Da Da,* Pa
kan na tan dri . na . Pai . . Ka ru . . ni m . chu
ma ; ma; /
ma ni (Though there is a slight touch of Pa in the two ma's)

23. The notes or svaras formed at aliquot parts of the Shadja and the Panchama strings, namely, 2, 3, 4, 5, 6, 7, 9 and 10 from meru excepting 8, have been shown, and dealt with in the previous paras. R. F. 8/7 will be referred to later when my paper in "Current Science" of Bangalore No. 8 of August, 1949. will be dealt with, vide G M. Page 142 etseq. (para 30 *supra.*)

24. **Ahobala - His measurement of vibrating lengths.**

24.1 A curious reader might ask whether any Indian in the past actually measured vibrating lengths of the speaking wire,

and determined the svaras, like the Greeks as referred to in para 9.1. Yes. According to Mr. Bhatkande's book "A comparative study of some of the Leading Music Systems of the 15th, 16th, 17th and 18th centuries." It is Ahobala, of the latter half of the 16th Century, the writer of Sangeeta Pārijāta. Transcribing briefly Bhatkande's observations thereof, at pages 27 to 30, it may be stated thus.

24.2 In a veena wire of 36 inches, higher Shadja is at 18 inches from Meru ; ni at 16 inches from meru ; Pa at 12 inches from meru ; Ma at 9 inches from meru ; ga at 6 inches and Ri at 4 inches ; however, the position of Da was somewhat left loose and it was to be decided on the *Samvadi* relationship. That is to say, this was the Suddha scale of Ahobala, which corresponds to modern Kharaharapriya or Hindustani *Kafi* That. The R.F's of Ṡa, ni, Pa, Ma, ga, Ri are respectively 2, 9/5, 3/2, 4/3, 6/5 and 9/8. If Da were decided with relation to Ri, it would be 27/16 which the Hindustanis now say it is. [One school of Ahobala has held Da has R. F. 12/7 and so Ri will be R. F. 8/7 C.S.]

24.3 According to South Indian interpretation of the earlier Sangeeta Ratnakara of Sārangadev, 'Suddha' svaras are the notes in the scale, as now placed on the South Indian veena for the very same raga or Bhairavi of South India, *i.e.*, they are 1, 10/9, 32/27, 4/3, 3/2, 5/3, 16/9 and 2 in the ascent. It is, however, observed by Bhatkhande at page 33 that though Ahobala had used 29 svara names (for *srutis*) in his music system, he never used more than 12 svaras. It is evident from Bhatkhande's further observations Ahobala did *not* know the svara elicited from 1/5th of the string from Meru (or nut of the violin), R. F. 5/4.

CHAPTER – VII.

25. Helmholtz and the 22 intervals in the Octave.

25.1 It is said that before Helmholtz, the tuning of the piano to equal temperament, vide para 14.6, was not perfect, and it is to his credit that by the method of Sa Pa and Sa Ma bases with the playing of the chords, as smoothly as possible, that the system was perfected and understood by the practical tuner. The modus operandus is given in the appendix, as far as we have understood it.

25.2 It is evident from the sub-joined extract taken from the chapter "Arabic and Persian Musical Systems" 5th English Edition 1930, pages 280 – 81 that he understood the frequencies, which arise by *calculations* by the Sa Pa and Sa Ma bases. It would appear that the Arabic system did not know the method of tuning by 5ths which the Greeks followed. This Persian system which goes by the Sa Ma bases was, as he said, an improvement on the Pythagorean system of fifths.

25.3 Extract from Helmholtz Chapter XIV, "Arabic and Persian Musical System" – page 280 – 81, Ellis's translation, 1930.

"By tuning four Fifths upwards from C

(1) C $\pm$ G $\pm$ D $\pm$ A $\pm$ E

N.B. G D A $\dot{E}$ is the European's violin tuning today. (C.S)

We come to a tone, E, which is 81/80 or a comma higher than the natural major Third of C, which we write E_1. The former E forms the major Third in the Pythagorean scale. But, if we tune eight Fifths downwards from C. thus

(2) $C \pm F \pm B_b \pm E_b \pm A_b \pm D_b \pm G_b \pm C_b \pm F_b$ @

@ Note please the nomenclature of the last three notes. The spiral system of naming the notes in J. J. Page 166 may be consulted re. flat, b; double flat, bb; sharp, $\S$ and double sharp, x; C. S.

"We come to a tone, F_b which is almost exactly the same as the natural E_1. The interval of C to F_b is expressed by

$$\frac{8192}{6561} = \frac{5}{4} \times \frac{32768}{32805} \text{ or nearly } \frac{5}{4} \times \frac{885.6}{886.6} (= 384 \text{ cents})$$

Hence the tone F_b is lower than the natural major Third E_1 (= 386 cents) by the extremely small interval $\frac{887}{886}$ (2 cents) which is about the eleventh part of a comma (= 22 cents). This interval between F_b and E_1 is practically scarcely perceptible or at most only perceptible by the extremely slow beats produced by the chord C . . F_b . . G (= C 384 Fb 318 G) upon an instrument most exactly tuned. Practically, then we may without hesitation assume that the two tones F_b and E_1 are identical, and of course that their Fifths are also identical, or

(3) $F_b = E_1$,$C_b = B_1$, $G_b = F_1$ $\S$ &c.

(Even in the first German edition 1862 of H:)

25.4 **Explanation of the author of 1, 2 & 3 in para 25.3.**

(1) (Sa-Pa bases ; add 702 cents for 3/2 R. F. subtract 1200 cents or divide by 2 if the figure goes above 2).

	C	G	D	A	E	B	F §
	Sa	Pa	Ri	Da	Ga	Ni	ma
					**	***	
R. Fs.	1	3/2	9/8	*27/16	81/64	243/128	729/512
Cents	0	702	204	906	408	1110	612

* Pythagorean Major Sixth ;

** Pythagorean Major Third ;

*** Pythagorean Major Seventh ;

(2) (Sa-Ma bases ; add 498 cents for 4/3 R. F. and subtract 1200 if the figures rises above 2)

	F	B_b	E_b	A_b	D_b	G_b	C_b	F_b
R.Fs.	4/3	16/9	32/27	128/81	256/243	1024/729	4096/2187	8192/6561
Cents	498	996	294	792	90	588	1086	384
Svaras	Ma	ni	ga	da	ri	ma	Ni	Ga

The natural major Third E_1, = 386 cents, whereas E the Pythagorean Major Third is 408 cents, the difference being 22.

(3) We must explain the suffixes in E_1 and B_1. That means a reduction of 22 cents, or R. F. 81/80 from the Pythagorean Major Third and Pythagorean Major Seventh respectively. The notes of the harmonical – H Page 17 - will be clear from the notation adopted herein, *vide* para 13.2 and 13.5.

25.5 If one now studies H page 17 - para 13.2 one should notice that besides D_1 and D which are true notes and C. F. & G. that is Shadja, Suddha Madhyama, and Panchama, which are also true and prolongable, the following notes, namely, the minor Third, the Minor Sixth and the Minor Seventh, (E_b, A_b and B_b) obtained from the Sa-Ma basis have to be raised by a comma in pitch to become true notes; and

similarly the notes the Major Third, the Major Sixth and the Major Seventh (E, A and B) obtained from the Sa-Pa basis have to be *lowered* by a comma in pitch to become true notes.

25.6 The author himself has said this in a different manner by his studies and verification with 8 standard tuning forks of the changes in scale for each tuning fork, of the 19 notes, which can be heard there from and that the above frequencies in para 25.5, besides others, *vide* para 13.5 and that these frequencies do not coalesce with the drone vide conclusions* at page 71 G.M. 1939 and repeated, page 73 2nd edition 1951.

Equal temperment.

25.7 Now for the definition of equal temperment on the piano :

The Octave on the piano is divided into 12 equal intervals. *i.e.*, each interval being mathematically the 12th root of 2 since the Octave is R. F. 2 as compared with fundamental 1 ; the European generally works out the ratio as equal to 1200 cyclic cents, each interval being 100.

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*conclusions.

" As for every fundamental pitch of a singer, the listener is able to say that music is true in every raga which the artist sings or plays, I believe the ear adjusts itself to *harmonic* notes arising from such Sa and Pa of the drone.

Having found five at least of these *complex* ratios namely 32/27, 16/9, 27/20, 45/32, 64/45 and 40/27 on the Sa Pa and Sa Ma bases, absent generally in our music *i.e.*, not present as prolonged Svaras, I presume we have to discard, if not entirely, the evaluation in our music of to-day, of the *srutis* on the Sa Pa and Sa Ma bases."

C = 0 ; d = 100 ; D = 200 ; e = 300 ; E = 400 ; F = 500 ; f = 600 ; G = 700 ; a = 800 ; A = 900 ; b = 1000 ; B = 1100 ; and C = 1200

(All expressed in logarithmic cyclic cents and have been explained in G.M.)

25.8 **Quartertones.**

The harmonical was constructed so that students should be able to hear the exact intervals in pitches spoken of in H page 17, para 13.2. The word quartertone is used to denote frequencies of less than a diatonic semitone (R. F. 16/15) or 112 cyclic cents, and H has referred at page 17 to the following quartertones except item (iv), besides R F. 81/80, the comma.

(i) R. F. 21/20 = 85 cents subminor second ; (ii) R. F. 25/24 = 70 cents, small semitone; (iii) R.F. 36/35 = 49 cents. (the ratio of 9/5 to 7/4); (iv) R.F. 128/125 = 42 cents, Diesis; vide para 17 block ' D ' ; and para 17.2.

26. **Chart of 22 frequencies from A. H. F. S. (L).** P. 311.

	European Notes	European semi-tones	European Scale	Sruti	Hindu additions	
					Scale	Deriva-tion
22	$\dot{C}$	...	1200	...	...	...
21	...	112	...	+22	1110	B+
20	B	...	1088	...	...	...
19	...	92	...	+22	1018	B_b+
18	B_b	...	996	...	...	...
17	...	112	...	+22	906	A+

	European Notes	European semi-tones	European Scale	Sruti	Hindu additions	
					Scale	Derivation
16	A	...	884	...	...	...
15	A_b	70	814	...	...	...
14	...	...	...	—22	792	A_b—
13	G	112	702	...	...	...
12	G_b	92	610	...	...	...
11	F§	...	590	...	...	...
10	...	92	...	+22	520	F+
9	F	...	498	...	...	...
8	...	112	...	+22	408	E+
7	E	...	386	...	...	...
6	E_b	70	316	...	...	...
5	...	112	...	–22	294	E_b–
4	D	...	204	...	...	...
3	...	92	...	–22	182	D–
2	D_b	...	112	...	...	...
1	...	112	...	–22	90	D_b–
0	C	...	0	...	...	...

26.2 Referring to the above chart, an extract from the review of G.M. 2nd edition, by J. M. Barbour in "Notes" of the Music Library Association September, 1953, Second series Volume X, No. 4 (Library of Congress, Washington) is given below :—

> "In the microtonal scale of 22 srutis, as presented by Fox Strangways and others, each semitone of the octave, save C and G (Sa and Pa) has both a Pythagorean and a just tuning, these "twin" frequencies differing by a comma (81/80 or 22 cents). But, says Ayyar,...."

(The review will be continued at a subsequent stage of the book.)

26.3 This chart of Fox Strangways may be of theoretical interest and does not differ at all in any way from the extract/from H, para 25.3 and yet this chart is taught in the University classes at Madras as the frequencies in the gamakas occurring in South Indian melodies. I doubt with what propriety, vide page 70 and 71 of P. Sambamoorthy's "South Indian Music" – Book V (University of Madras) (1951.) It may be noted here that Fox Strangways (L) does not follow the signs for flats and sharps given in J. J.'s spiral page 166.

N. B. :—He has in his 'Music of Hindostan' (1914) referred at page 116, to the work of Deval and Clements.

CHAPTER - VIII

27. Manner of approach for semi-tone intervals.

27.1 In the author's early lessons on the violin from Vidwan Sabhesa Iyer, in the year 1919 in the practice of *Sarali Varisai* or musical exercises, in Maya Malava Gowla Raga,

(scale Sa ri-Ga Ma; Pa da - Ni Ṡa both in ascent and descent) and in the first grip of the violin position, when playing on the open strings Sa and Pa respectively, that is, when the index finger, the middle finger, and the ring finger respectively touched ri, Ga, Ma on the string, and similarly in the same order the index finger, the middle finger, and the ring finger touched da, Ni, and Ṡa there was a feature that in playing in *medium* tempo the phrase already given, that the ring finger touches Ma or Ṡa before the middle finger produces Ga or Ni respectively.

27.2 But the sounds of Ma and Ṡa connected with this Ga and Ni respectively are *not* pronounced, in vocal music.

27.3 This aspect was subsequently noticed by the author long afterwards, as nokkus (w) on Ga and Ni respectively in Subbarama Dikshitar's book "Bala Siksha" 1905 page 15 as Sa ri – $\overset{w}{\text{Ga}}$ Ma; Pa da – $\overset{w}{\text{Ni}}$ Ṡa. (refer G. M. page 49).

27.4 A slight pull across the fret of the veena, to raise the particular note there in pitch, is called a *nokku*, meaning 'press' in Telugu. The symbol 'w' above svara is used by Subbarama Dikshitar to denote the gamaka in question (Page 11 of the Tamil portion and at page 2 of the Telugu passages explaining the various gamaka signs intended for veena play), in his magnum opus, 1904.

27.5 For the violinist, the nokku w simply connotes the touch of a svara (note) *just* higher than that on which the sign w is placed, in the scale of the raga or the piece.

27.6 One must understand therefore that there is a way of approach for Ga and Ni in that raga; and that there are a number of unpronounced svaras in our music.

27.7 The explanation is, to the author's mind, that from ri to Ma, and particularly from da to Sa, there is a *step-up* of a harmonic interval of 5/4 and then the voice is dropped to the lower Ga and Ni, when there is noticeable a slight rise in their pitches, probably dropping only to 70 cents from Ma and Ṡa instead of the full semitone of 112 cents.

27.8 A few examples of nokku sign w from Subbarama Dikshitar's book are given below :–

(a) w w
ni Sa, ni – Sa Ri - Ri *ga* Ri-Sa, (from the song
. . . len da ro ma Endaro of Tyagaraja
(Sri Raga) page 92
line 2 Anubanda B.)

This really means

(Sa) \ (Sa) \ Sa's above the line of svara
ni Sa, ni are just touches.

w . . . (from the song Jaya Jaya Gokula
(b) Da ni Sa Ri Sa, – (Bhairavi - South India)
Ja ya Ja ya Go Page 68, Anubandha B.)

We can almost assert that the svaras ni, ma and ga are *not* shown *without* a nokku sign, in the play of the veena in general, in ascent.

28. **The small semitone** (R. F. 25/24 70 Cyclic cents).

28.1 If one plays on the violin, say, Sa ri Ga ri Sa and Pa da Ni da Pa phrases - the necessity for a harmonic interval between ri and Ga, and between da and Ni would require ri and da to be respectively 25/24 R.F. on Sa string and R.F. 25/16 on Pa string, the corresponding position, giving a minor third or R.F. 6/5 interval; 25/24 x 6/5 equals 5/4; 25/16 x 6/5 equals 15/8 - page 49 G. M.

28.2 As a further illustration the use of the small semitones from Sa and Pa are found tn the *Geetham* in Malahari raga ; (R F. 25/24) will be shown as ri$\frac{1}{2}$ and R. F. 25/16 as da$\frac{1}{2}$. Janya in Mayamalavagowla

w Ṡa Pa w
Ma Pa da Ṡa Ṡa . ri$\frac{1}{2}$ / ri$\frac{1}{2}$ Sa da$\frac{1}{2}$ Pa Ma Pa /

Ma Pa
ri Ma Pa da Ma Pa / da$\frac{1}{2}$ Pa Ma Ga ri$\frac{1}{2}$ Sa /

Sa, ri Ma Ga ri$\frac{1}{2}$ / Sa ri$\frac{1}{2}$ Ga ri$\frac{1}{2}$ Sa etc. /

28.3 This early lesson will illustrate the step-up of R. F. 5/4 or major Third interval from ri to Ma, and the step-up of R. F. 6/5, minor Third interval from ri$\frac{1}{2}$ to Ga or the same step-down from Ga to ri$\frac{1}{2}$.

29. **Andolika gamaka** *i. e.* movement in the same svara.

29.1 The results of the two scientific papers of the author on "Microtonal variations in frequencies in Karnatic Music " of August 1949 and February 1953 in Current Science of Bangalore, already alluded to may be stated here. The oscillograph records of the author's violinplay were taken at the National Physical Laboratory, London in February, 1934 and were studied later by Physicists.

29.2 Re. ri and da of Saveri raga ascent Sa ri Ma Pa da Ṡa descent Ṡa Ni da Pa Ma Ga ri Sa. the Andolika gamaka in the two svaras may be stated, as under :-

The variation in da is from R. F. 25/16 (772 cents) - a small semi tone above Pa (702 cents) to R. F. 8/5 (814 cents) - a semitone above Pa. The variation in ri is from R.F. 25/24 (70 cents) to R. F. 16/15 (112 cents). The variation is 42 cyclic cents in each case and a comma variation is insufficient.

29.3 This illustrates to some extent how the voice manages a 112 cents or the semitone interval in the ascent from Sa to ri and Pa to da.

29.4 The quotation for Barbour's review is continued "But, says Ayyar, when the augmented second, D flat to E (ri to Ga) occurs in a melody, the law of consonance requires it to be rendered as a minor third (6:5) C-sharp to E. Thus arises the enharmonic interval, C sharp to D flat, known in Europe as the diesis (128:125 or 41 cents) (really 42 cylic cents C. S.) There are 6 such intervals in the octave."

29.5 Therefore, the use of R. F. 25/24, the small semitone, is proved in our music. The reviewer has noticed 6 instances of diesis, 42 cyclic cents; 2 of them have been noticed in the oscillograph records. Since 42 cents is the difference between 112 and 70 cents, one would naturally look up all cases of 112 cents. They are - (i) Ma (R. F. 4/3) to Ga (R. F. 5/4), (ii) Ṡa (R. F. 2) to Ni (R. F. 15/8), (iii) Pa (R, F. 3/2) to ma (R. F. 45/32). Therefore, the difference of 70 cents from Ma, Ṡa and Pa would give the frequencies R. F. 32/25 R. F. 48/25 and R. F. 36/25, respectively called the diminished fourth, diminished octave and the Acute diminished fifth ; R. F's. 32/35, 8/5, 48/25, form a major chord *vide* H. - P. 186 foot-note.

29-6 The last instance is a 70 cents rise from Ma or R. F. 25/18, as in the case of the rises from Sa and Pa in the oscillograph records. This would mean a movement from 25/18 to 64/45 R. F. and both are not concordant with the drone and we have met *no* such examples of *movements* in the kritis,

30. **Andolike gamaka** of a second type from Oscillograph record. (49 cyclic cents).

30.1 The variation in Ri of Madhyamavati raga (ascent Sa Ri Ma Pa ni Ṡa; descent Ṡa ni Pa Ma Ri Sa) within the same

svarā, is from R. F. 10/9 - (a minor tone above Sa) to R. F. 8/7 *i. e.* a measure of 49 cyclic cents (R. F. 36/35) and the comma variation is insufficient.

30.2 Similarly, the Andolika gamaka in Da of Begada raga (in the phrase Pa Da, Pa - Sa) *i. e.* within the same svara Da, is from R.F. 5/3-major sixth-(a minor tone above Pa) to R. F. 12/7, envisaging a ratio of R. F. 36/35 - 49 cyclic cents – subsisting between R.F. 9/5 and R. F. 7/4 vide - H page 17; and a comma variation is insufficient.

30.3 Here come in the frequencies at the aliquot part, 1/8th from the nut, on both the Sa and Pa strings; please refer Tables I and II para 17.1 and 18.2, wherein R. Fs. 8/7 and 12/7 have been denominated the super second and super major sixth respeetively - H pages 187 and 456 - vide block B in both the tables.

30.4 The review of Mr. Barbour is continued below; the author's apology is that he has been understood for the first time since the publication of G. M, 1939.

> " Moreover, when an initial B-flat (ni) is intoned with the aid solely of a C drone, the interval is likely to be a just seventh with 7:4 ratio. considerably lower than the usual 9:5. The two B-flats have a septimal ratio of 36:35 or 49 cents. There are 4 such intervals in the octave. These 10 additional srutis of 41 or 49 cents suggest quarter tones to the Westerner's ear more readily than does the 22 cent comma. The most conclusive test of Ayyar's theories was given by an oscillograph record of his violin playing, which showed that, at least in " andolikas " (vibrato-like graces), quarter tone intervals do exist in actual practice."

30.5 The four instances of 49 cyclic cents noticed by the reviewer are (i) R. F. 9/5 to R. F. 7/4, (ii) R. F. 6/5 to R. F. 7/6,

vide H pages 17 and 212; (iii) R. F. 8/7 to R. F. 10/9 (iv) R. F. 12/7 to R.F. 5/3 vide Oscillograph records. There is a 5th instance noticed by H., R.F. 9/7 to 5/4, H page 187. An observation may be made here by the author that R. F. 9/7 is a step-down of R. F. 7/6 from Pa R.F. 3/2, which leads the author to some important conclusions, which will be stated in due course.

30.6 The author's second scientific paper of Feb '53 also alludes to the existence of R.F. 7/6 (Septimal minor third) as occuring in the Todi ga (ascent : Sa ri ga Ma Pa da ni Ṡa ; descent ; Ṡa ni da Pa Ma ga ri Sa) called black note scale, by the Westerner.

31. **The quarter tone** R. F. 21/20, 85 cyclic cents denominated *sub minor second.*

31.1 The following instances may be mentioned :-

(i) Between R.F, 7/4 (harmonic minor seventh) and R.F. 5/3 (major sixth) - H Page 17.

(ii) Between R. F. 7/6 (septimal minor third) and R. F. 10/9 (minor tone) in the corresponding positions on Sa string.

(iii) Between R. F. 6/5 (minor third) and R. F. 8/7 (super-second) H page 187.**

(iv) Between R. F. 9 / 5 (minor seventh acute) and R F. 12/7** (super major sixth)

** vide oscillograph records.

CHAPTER - IX.

32. **Harmonic** stepping-up or down.

32.1 G. M. (1939) has the following paragraph at page 75, discussing a proposed theory of Karnatic music :– (repeated page 77 G. M. 1951, to replace the complex ratios given by A. H. F. S.)

> " The voice stands at particular harmonic notes, which are formed by aliquot parts of Sa and Pa Strings or at their simple nodes. The voice generally takes from such harmonic notes a longer reach and then drops to the adjacent note of the selected scale. When it goes direct to an adjacent note by a measure of a pitch of less than the semi tone, the adjacent note itself must be a harmonic note. "

The last sentence thereof may be illustrated by the use of R. F. 21/20 in the following examples

(i) Khamboji raga Da, ni Pa Da. The first Da is R. F. 5/3 major sixth and the ni is R. F. 7/4 septimal seventh ;

(ii) Bhairavi raga; ga ga Ri, Sa The ga's are R. F. 7/6 septimal minor third and the Ri, is R. F. 10/9 the minor tone. R. F. 10/9 is the characteristic of Bhairavi, South Indian raga. In fact, the ga's are in gamaka from Ri.

(iii) The illustrations of R. F. 21/20 given in para 31.1 items (iii) and (iv), are to be found in the Kharaharapriya raga ; in the kriti of Sri Tyagaraja 'Chakkani Raja', the word cha is the prolonged Ri R. F. 9/8 ; but the voice stops there. In the phrase for instance, Ri ga Ma Pa Da ni/ the stress is more upon the ga and ni which have frequencies 6/5 and 9/5 when the Ri and Da step-up to R. F. 8/7 and 12/7 respectively, bringing

about intervals of R. F. 21/20. This is also clear in the kriti "Pakkala Nilabadi" where the word ka goes up in gamaka movement upto R. F. 9/5. In fact, the characteristic of Kharaharapriya rests in the prominent use of R. Fs. 6/5 and 9/5. The word 'chi' in "Chikkanipalu" in the Annupallavi however starts with Da, R. F. 5/3 long.

33. **Gamaka signs.**

33.1 They were introduced into writing of music in the year 1904 by Subbarama Dikshitar at the instance of Sri Chinnaswami Mudaliar, who published music in European staff notation but felt that it was not sufficiently expressive. Hence, Subbarama Dikshitar's magnum opus mainly for Dikshitar's kritis was produced. The signs were intended for comprehension of music by veena players and came to my notice in 1942. The sign 'w' was one of those 11 signs then brought into vogue.

33.2 We have already expressed the meaning of the word 'nokku' in para 27.4, and explained what it means for the violinist in para 27.5. What it stands for in musical expression in terms of physical constants or notes has been slightly alluded to in para 27.7, in the treatment of the phrases in Maya Malava Gowla raga. In Maya Malava Gowla raga, there was a step-up of the harmonic interval of 5/4 major third from ri to Ma and from da to Ṡa and there was a rise in pitch of Ga and Ni by 42 cents bringing them close to Ma and Sa with an interval of 70 cents only.

Illustration of reduction in Semitone.

Raga : Mayamalava Gaula

Sa ri Ga Ma Pa da Ni Ṡa

Anupallavi of Tyagaraja's Tulasidala

w w w w
Ni Ṡa-Ni Ṡa – Ni Ṡa Ṡa Ni Ṡa ṙi Ṡa; Ġa ṙi Ṡa
Pa lu Maa – ru chi – ra – ka a la mu

Ni's are all only 70 cents from Ṡa ; Even ṙi is 70 cents above Ṡa.

33.3 We shall now deal with some major ragas where 'w' sign is placed on some of the svaras.

33.4 Raga : Hanumat Todi ; Mela : 8

w w
Sa ri – ga Ma / Pa da – ni Ṡa

The voice steps-up a 5/4 interval from ri to Ma and also from da to Ṡa. The svaras Ma and Sa are just touched in the four finger technique of the violin; and in the ascent the ga and ni are R. Fs. 6/5 and 9/5 and in the descent R. Fs. 7/6 and 7/4 respectively.

33.5 Raga: **Bhairavi** (Karnatic) in ascent ; Mela : 20.

w w
Sa Ri - ga Ma / Pa Da - ni Ṡa

The voice steps-up a 6/5 (a minor third) interval from Ri (R F. 10/9) to Ma ; and also from Da to Sa. The svaras Ma and Sa are just touched in the four finger technique of the violin; in the ascent ga becomes R. F. 6/5 and ni R. F. 9/5 and in the descent ga is R. F. 7/6 and ni R. F. 7/4 respectively.

33.6 Raga : **Sankarabharana** ; Mela : 29.

w w
Sa – Ri Ga – Ma / Pa – Da Ni – Ṡa

The voice steps-up a major third interval (R. F. 5/4) from Sa to Ga and from Pa to Ni. The svaras Ga and Ni are just touched, because Sa and Pa are open strings on the violin. In the ascent Ri is raised from R. F. 10/9 to 9/8 and Da is raised from R. F. 5/3 to 27/16.

34. **Harmonic stepping.**

34.1 This harmonic stepping is more *noticeable* on the violin, and was actually noticed by the author long before he had access to Subbarama Dikshitar's book.

34.2 The orthodox tradition about the higher sruti of a selected svara as used in ascent (Aroha), and the lower sruti of the same svara in descent (Avaroha), is maintained even in the explanations offered, just as there is a strain while we walk up and less tension when we go down the steps.

CHAPTER – X.

35. **The proposed theory for Karnatic Music** : a few additional observations.

35.1 In addition to the 12 prolongable notes given in H's harmonical page 17, we have found in our music R. Fs. 7/6 and 7/5 and examples thereof were given. We have also been able to trace in our gamakas the 42 cents interval, and the 49 cents interval in certain phrases of ragas. We have also pointed out how the semitone interval of 112 cents gets reduced to 70 cents, especially in ascent owing to the harmonic stepping.

35.2 Any student, who has followed me so far, would realise that the 49 cents interval (R. F. 36/35) is just the difference between the just minor third (R. F. 6/5) and the septimal or subminor third (R. F. 7/6) and we have noticed 5 instances of such 49 cents interval, including the two, which came under our study. And the discovery of R. F. 8/7, (the super second) and R. F. 12/7, (the super major sixth,) in our music and also the occurrence of R. F. 7/6, septimal or subminor third, forces me to a logical conclusion, as below :—

35.3 R. F. 4/3 (Suddha Madhyama) to R. F. 8/7 (super second), is a step down by R. F. 7/6 (septimal minor third). Similarly, higher shadja R. F. 2 to R F. 12/7, super major sixth, is the same step-down of R. F. 7/6, the septimal minor third. Therefore, besides the step-up or down from *prolongable* notes recognised by the European, by R. F 5/4, the major third, and by R. F. 6/5, the just minor third, in karnatic music, there is also a similar step-up or step-down by R. F. 7/6, the septimal minor third. This allows a *short circuting* of the just minor third ratio by 49 cents, when there is no intermediate note, curving round, as it were, to a sweet note, though we may not be able to stand there long. This idea is reinforced by Helmoltz referring to R. F. 9/7 (super major third) at page 187, as this is just a step-down of R. F. 7/6 from R F. 3/2.

35.4 Illustrations of the septimal minor Third, step-up or down

(1) Raga : Suddha Bangāla
Scale : Sa Ri Ma Pa Da Ṡa - Ṡa Da Pa Ma-Ri ga Ri Sa
Sa, Sa - Ri, Ri, - , *Sa Ri* Ma, Ri ga *ga Ri Ri Sa*
Ra ma Bhak Ti Saa m Raa Jya m
Sa Da -

N. B. : All subsequent sangatis have the commencing words Rama (Sa, Sa)

Explanation : The last Da is septimal minor third drop from Sa and the music rises to Sa of the opening line. Note the intermediate ni is missing.

Ri is R. F. 10/9 in the drop from Ma, - (Word Saam Raa)

(2) Raga : Kambhoji
Scale : Sa Ri Ga Ma Pa Da Ṡa-Ṡa ni Da Pa Ma Ga Ri Sa

From the varna, tarunee.

/ Sa \
Pa, Da, Sa, Ri ni Da Pa
ta ru nee

Explanation : Da is a septimal minor third step-down from Sa crushed note.

(3) Raga ; Purva Kalyani

Ar. Sa ri Ga ma Pa Da Pa Ṡa
Av. Ṡa Ni Da Pa ma Ga ri Sa
Sa \ / /
Da ,, Sa ri Ga Pa ma
Gna na mo sa ga (Tyagaraja's Kriti)

Explanation : Da – is reached by a septimal step-down from Sa, crushed note, as a slide.

36. **MUSICAL INTERVALS not exceeding one Octave,**

Svara	Cyclic cents	R. F.	NAME	South Indian Name	Remarks
Sa	0	1	Fundamental	Shadja	
..	22	81/80	Comma		
..	42	128/125*	Great Diesis.		See research paper.
..	49	36/35*	Interval between harmonic septimal 7th (R.F. 7/4) and acute minor 7th (R. F. 9/5) or between 6/5 and 7/6.		Do
ri	70	25/24*	Small semitone		See research paper.
	85	21/20	Subminor second		
	112	16/15	Diatonic or just semitone.	Suddha Rishabha	

Svara	Cyclic cents	R. F.	NAME	South Indian Name	Remarks
Ri	182	10/9	Minor tone of just intonation.	Trisruti Rishaba	
	204	9/8	Major tone (9th harmonic)	Chatursruti Rishaba	
	231	8/7*	Super or Septimal 2nd.		See research paper
ga	267	7/6*	Septimal or subminor 3rd		See research paper
	316	6/5	Just minor 3rd.	Sadhārana Gāndhara	
Ga	386	5/4	Just major 3rd (5th harmonic)	Antar-*Gata* Gāndhara	See N. B.
	428	32/25	Diminished 4th.		
	435	9/7	Septimal or *super*-major 3rd.		
	471	21/16	Septimal or sub-fourth (21st harmonic)		
Ma	498	4/3	Just and Pythagorean 4th.	Suddha Madhyama	
	551	11/8	11th Harmonic		

MUSICAL INTERVALS not exceeding One Octave.

ma	583	7/5	Septimal 5th.		
	590	45/32	45th Harmonic.	Prati-Madhyama.	
	632	36/25	Acute diminished 5th. [6/5 x 6/5]		
	617	10/7	A drop of R.F. 21/20 from Panchama.		

Svara	Cyclic cents	R. F.	NAME	South Indian Name	Remarks
Pa	702	3/2	Just and Pythagorean 5th.	Panchama	
da	772	25/16*	25th Harmonic (Grave superfluous 5th). 5/4x 5/4		See research paper.
	814	8/5	Just minor 6th.	Suddha Dhaivata	
	841	13/8	13th Harmonic.		
Da	884	5/3	Just major 6th	Trisruti Dhaivata	
	906	27/16	27th Harmonic.	Chatusruti Dhaivata.	Pythogorean Major 6th
	933	12/7*	Supermajor 6th		See research paper.
ni	969	7/4	7th Harmonic (Septimal)		
	1018	9/5	Minor 7th (Acute)	Kaisiki Nishāda.	
	1050	11/6	Fourth of R. F. 11/8		Prolongable note.
Ni	1088	15/8	Just Major 7th.	Kakali Nishāda.	
	1129	48/25	Diminished Octave.		
Sa	1200	2	Octave	Higher Shadja	

N. B. against 386 cents :

Note : The natural note of the human voice Ga is slightly sharper than that on the vina fret R. F. 5/4 see para 13 *infra*. e.g., Ga long, in the Kriti 'Tulasidala' in

(1) the phrase To sha mu gaa
Sa ri Ga Ga Ga, Vide page 50 G.M.

(2) e. g. Ga long in the Kriti 'Meru Samāna' in the starting phrase.

; - *ri* *Sa* Ni , Saa ri - Ga ri Gaa ; Maa
Me ru Sa Maa na

37. **Observations on certain notes** (svaras) given in para 36, Musical intervals not exceeding one Octave.

37.1 Many of them have been commented upon in the previous paragraphs. It is proposed only to give a few observations on those R. Fs. not previously mentioned.

37.2 No comments are necessary on the first three items after shadja.

37.3 ri may be R. F. 25/24, R. F. 21/20 or R. F. 16/15. The note R. F. 21/20 (subminor second) occurs as a prolongable note in the Punnagavarali raga, in the song Kanaka Saila of Shyama Sastri against the vowel in Sai. This is a characteristic note in Todi also as in Sa ri Sa - when played on Panchama string of the violin. The first two svaras are prolongable. R. F. 16/15, generally is a short svara and occurs in gowla raga in the phrase Ga Ma ri Sa as a step-down of R. F. 5/4 (major third).

37.4 Ri may be R. F.'s 10/9, 9/8 or 8/7. The last, R. F. 8/7, however is generally short or in gamaka. As this svara R. F. 8/7 (super second) is a step-down by a septimal minor third from R. F. 4/3 (Suddha Madhyama) it occurs generally when there is *no intermediate* note between Ma and Ri. For instance, in Mukhari raga Ri, Ma - Pa - in the ascent, the Ri is the supersecond. Again in the phrase Pa ni, *ni Da* Da, Sa - the ni, is R. F. 9/5 (acute

minor seventh) and the last Da, becomes R. F. 12/7 (super major sixth). (In Da, Sa there is no intermediate note) Another example may be cited where in the kriti 'Maye' of Dikshitar in the phrase Pa ni *ni Da* Da Sa, the ni's are only R. F. 7/4 owing to the earlier part of the song, where Ga is present. This is just to illustrate a different aspect.

37.5 ga may be R. F's 7/6 or 6/5, that is the septimal minor third or the just minor third; both are prolongable notes.

37.6 Ga - There is no need to comment further upon R. F.'s 5/4 and 32/25. R. F. 9/7 (super major third) is a step-down of a septimal minor third from Panchama. It occurs in the raga Hamsadhwani as in the phrase Ga Pa Ga Ri Sa. One can feel in the violin the distinct position of the first Ga, above the major third, R. F. 5/4.

R. F. 21/16, (septimal or sub fourth) probably occurs specially in Kalyani raga, where panchama is a prominent svara, as this svara is the seventh harmonic partial of Panchama, and appears in gamaka. It should not be confused with the Suddha Madhyama or true fourth.

37.7 Ma, R. F. 4/3 (Suddha Madhyama). This note is *not* an upper partial, but an inverted fifth of the octave. R. F. 11/8, is an upper partial of shadja, 11th harmonic, associated, probably with Ma of Begada in gamaka.

37.8 ma, R. F. 45/32, the 45th harmonic, but *not* used as such on the fret of the veena. R. F. 7/5, (septimal or sub minor fifth) is a true note and heard resonantly in Vachaspati raga, *vide* para 22. R. F. 36/25, acute diminished fifth, which is equal to 6/5 x 6/5, is likely to occur in Pratimadhyama raga, where it may be associated with ga, as in Simhendra Madhyama raga. R. F. 10/7, is equal to 3/2 ÷ 21/20 - *i.e.* - a drop of submino r second from panchama.

37.9 Pa - R. F. 3/2 the true fifth, unchangeable in melody.

37.10 da - may be R. F. 25/16, 70 cents above Panchama, or R. F. 8/5, 112 cents above Panchama. (The difference of 42 cents in the svara appears as andolika gamaka in Saveri raga, just as the same difference appears in ri as gamaka in the same raga from 70 to 112 cents above shadja). 8/5 is a true note to be associated with Ma or Sa.

37.11 Da-There is no need to comment further on the three notes R. F.'s 5/3, 27/16 and 12/7. R.F. 5/3, major sixth, is a prolongable note.

37.12 ni may be R. F. 7/4 (natural harmonic), prolongable note, or R. F. 9/5 (minor seventh acute) also a prolongable svara. Mention must, however, be made of another frequency R.F. 11/6 probably, which appears as a prolonged note in Nee of Nee Daya - Rada of the kriti in Vasanta Bhairavi raga of Tyagaraja ; or as in Nee of the song, Neera Jakshi, kriti of Dikshitar in Hindola.

37.13 Ni – R. F 15/8 (just major seventh) or R. F. 48/25, 70 cent-below shadja higher, vide para 27.7 about Maya Malava Gowla raga.

37.14 Ṡa The octave or higher shadja.

CONSONANTS

38.1 We have already referred to Helmholtz' dictum that consonants are but brief explosive noises. This fact, we refer to again, because in Raga alapanas some consonants are used. Previously they were Tam Nam. Both n and m are voiced consonants, and were good. But nowadays Ta Da Ri Na or Ta Da Ra Na have come into vogue, which are indeed harsh to listeners. Youngsters must avoid the use of the latter syllables.

39.1 Regarding the vowel sounds in our Music, they are sanskritic in content especially a-aa as in Rama or like the vowel sounds in the English word ' father ' or ' Calm ' long or short. It may be noted here that each vowel sound is characterised by two particular frequencies of fixed pitch, one low, the other relatively high, besides the pitch of the notes which is determined by the vibration of the vocal cords.

a (as in father)	...	... 825 c/s;	1200 c/s
u (as in moon)	...	... 400 c/s;	800 c/s
a (as in tame)	...	... 550 c/s;	2100 c/s
e (as in seem)	...	... 375 c/s;	2400 c/s
a (as in cap)	...	... 750 c/s;	1800 c/s*

It is unfortunate that the Tamilian has begun to use the vowel sound a as in cap, which he should avoid.

* quoted from Lowery's (p. 83) Guide to Musical Acoustics.

39.2 This aspect of vowel sounds brings to the forefront, the four extra notes, which are duplicate names for some of the fret positions namely, Suddha Gāndhāra, Suddha Nishāda, Shad-Sruti Rishabha and Shad-Sruti Dhaivata. We have already stated in the Grammar of Music the following opinions. "After listening to the huge composition MELA RAGA MALIKA of the Late Maha Vaidyanatha Sivan, as sung by his pupil Vidvan Sri Sabhesa Iyer.

	Commonly stated to be	Our opinion
1. Suddha Gāndhāra	Chatusruti Rishabha	Trisruti Rishabha 10/9, when prolongable and without gamaka
2. Suddha Nishāda	Chatusruti Dhaivata	Trisruti Dhaivata 5/3
3. Shad-sruti Rishabha	Sādhārana Gāndhāra	Frequency 6/5, harmonic on Sa string .
4. Shad-sruti Dhaivata	Kaisiki nishāda	Frequency 9/5, harmonic on Pa string .

It is pertinent to observe here that the four svaras, enlisted by the names in the first column, should be pronounced as ga, ni, Ri and Da in *svara* singing for purposes of euphony ; we have noticed the difficulty of pronouncing ga with a vowel ending a (अ) for the R. F. 10/9 which for the long while had been associated with the vowel sound ee (इ) of the svara Ri; and we have also noticed that Vidvan Sabhesa Iyer instructing a pupil (Veena Player) the method to facilitate this pronounciation ; 'place your finger at the second fret of the Shadja string of the veena ; listen to the sound which it produces, do not say Ri but ga at the very pitch and get yourself used to the 'a' (अ) intonation. This exactly is a proof of the different vowel pitches, involved in a and ee. Vide para 39.1.

39.3 There is a certain *logical* feature in the definitive names of svaras, suddha rishabha R. F. 16/15, and suddha gāndhāra R. F. 10/9, of South Indian nomenclature, which are obtained by the drop of a major third R. F. 5/4, and a harmonic just minor third R. F. 6/5 respectively from

Suddha Madhyama R. F. 4/3. Similarly, suddha dhaivata R. F. 8/5 and suddha nishāda R. F. 5/3 are derived by a similar drop from higher Shadja R. F. 2 respectively.

40. FINALE

40.1 We have seen in paras 29.2 and 27.7 how the semitone interval of 112 cents from Sa to ri and Pa to da in ascent and from Ma to Ga and Sa to Ni in descent has been reduced to the extent of a 70 cents interval, or the small semitone ; and in para 32.1, how the sub-minor second, R. F. 21/20, has replaced the semitone interval, in three instances. Further, the Semitone intervals *actually* existing on the *veena* from R. F. 10/9 to 32/27 and R. Fs. 5/3 to 16/9 and R. F. 45/32 to 3/2 on the shadja string have all *not* been used in the actual play.

40.2 H had referred to three of the above semitone intervals *i.e.*, Pa to da, Ma to Ga and Sa to Ni in his harmonical H page 17, and a fourth interval of the semitone from R. F. 9/8 (Ri) to R. F. 6/5 (ga) This too has been thrown out in actual music by the introduction of R. F. 8/7 to 6/5 and of R. F. 12/7 to 9/5 with the use of R. F. 21/20 in the Kharaharapriya raga ; though we use the prolonged notes of R. F. 9/8 and also R. F. 6/5.

40.3 It seems to us, therefore, the semitone *interval*, as such between prolongable notes, is not used in South Indian melodic music, and has been replaced either by the small semitone, R. F. 25/24 or sub-minor second; R. F. 21/20. The above observation, coupled with the fact that in South Indian music, there is also a harmonic step-up or down, by the interval of a septimal minor third, R. F. 7/6, in addition to the step-up or down by the major third, R. F. 5/4, and the just minor third R. F. 6/5, will completely denote the actualities, of the author's proposed theory of the

Karnatic music in lieu of "22 tone Indian scale" in the octave, now talked of. (See paras 35.3 & 35.4 infra.)

40.4 Physicists may object that the entire disregard of the semi-tone by the small semi-tone R. F. 25/24 or sub-minor second R. F. 21/20 as the next note of a prolongable note has not been verified or proved. To this, the author has only to say that his intuition for study of the gamakas in the Saveri ri and Saveri da and those in Madhyamavati Ri and Begada Da and his search for R. F. 7/6 as early as 1934 shows that here also the author can not have gone far wrong. The discovery of the use of 42 cents in our music (not mentioned at all in the Helm-Holtz's Sensations of Tone in the main book) and the similar use of 49 cents interval in the two instances noted for research by the author (not mentioned also in the main book but for H's three other examples) and his own experience of having written down with gamaka signs the two volumes of Tyagaraja's Kritis, 108 and 120, is the defence for such a statement. If this book will be an incentive for further scientific work, it is all that he looks for in younger generation of musicians cum physicists. The book perhaps must end here but the author has other general matters to mention.

N. B. to Para 40.4 ; The reader may question whether even in the case of the two prolongable notes Ga R. F. 5/4 and Ma R. F. 4/3, we cannot pass from one to the other, without cutting short the semi-tone interval of R. F. 16/15. Our experience has been, we have a gamaka from Ga to Ma (not exactly R. F. 4/3) as in Nilambari raga, or we raise up Ga after touching Ma R. F. 4/3, which is un-pronounced. A further example may be given : from the Yadukula Kambodi kriti :

; Sa Ri Gaa ; Gaa, Ga *Ga*a*a*, Ma *Paa*, Ma Gaa
Ye li ye nai ma *ra* *n* da ,

* here *Gaa*, rises in *pitch slightly*.

40.5 In our opinion, we must bid good bye to the plural word 'srutis' from the musical vocabulary; and in future, there should be no reference to the 'sruti' intervals or 'sruti' numbers, but only the word 'Sruti' *i.e.* the drone of the tambura.

41. Tambura and the Mridanga :

41.1 The strings of the tambura are tuned thus ; (Lower) Sa, **Sa,** Sa, (Lower) Pa, with frequencies 1/2, 1, 1, 3/4 counting from the position next to the Singer. See Plate 1, and thus R. F. 5/4 being the sum of the frequencies of the first and the last strings $(\frac{1}{2} + \frac{3}{4})$ is heard under the principle of summation tones. The strings are however, twanged Pa Sa Sa Sa *i.e.*, in the reverse order. (This is Panchama sruti G tuning.)

41.2 Occasionally the Tambura is also tuned as (lower) Sa, **Sa** Sa and (lower) Ma, towards the end of a concert. This is called Madhyama Sruti. (F tuning) ; the frequencies then are 1/2, 1, 1. 2/3. What was originally Sa of the singer becomes *Pa,* as it were, *of the music.* The relative frequencies are thus 3/4, 3/2, 3/2, 1. Note also the *jeevadhara,* the silk string underneath the wires and over the bridge to make the tone resonant, when the points of contact of the strings with the bridge are properly adjusted. See Plate 1.

41.3 *Re* the acoustical effect of the *'jeevadhara'* of the tambura and of the *curved* bridge of the Veena, the reader is referred to the paper on 'Some Indian Musical Instruments' by Sir C. V. Raman, F. R. S., N. L. in Vol. VII (1921–22) of the Pros. Indian Assn. for the Cultivation of Science, Calcutta. These Instruments give out powerful overtones or partials, having a node at the 'plucked point.'

41.4 A few words about the Mridanga used as a rhythmic accompaniment to melody both for vocal and instrumental music. The centrally loaded membrane gives out also the partials 2, 3, 4, 5 (alike on the Veena see para 17.) - *vide* Sir C. V. Raman's Paper on 'The Indian Musical Drums' in the Proceedings of the Indian Academy of Science, - Bangalore- Vol. 1, No. 4, Oct. 1934.

41.5 What has been said above refers to the right side of the Mridanga, where the central loading is of a paste of stone powder. For the left side, a paste of wheat flour and water is put in the centre during play and this helps to give a dull sound, Panchama.

42 Other musical instruments.

42.1 Gotu-vadyam : It is exactly like the veena in construction except that it has no frets to play on and perhaps it is an early instrument. The shadja string however, is duplicated by some, and the music is produced by a thin cylindrical, ebony, or glass, rod moved over the strings by the left hand and the plucking of the strings by a plectrum on the fingers of the right hand. It is known as 'Vichitra veena' in Northern India. As for melodic effect, the rubbing of the ebony rod over the strings, when passing up and down, produces a a slight harshness similar to the scraping of the bow on the violin, which cannot be avoided and it is very difficult instrument to play as the strings sag under the pressure of the rod. For purity and tone, the veena should certainly be preferred.

42.2 Flute : The transverse or side-blown flute, as shown in the modern pictures of Sri Krishna, is used for classical music in South India. It is made from bamboo hollowed out and has the natural cylindrical bore closed at one end *i.e.*, at

the *kanu* (knot) and open at the other. The blowing hole is fairly nearly the closed end and the eight other holes are for operating the svaras. The free blowing with no holes closed gives the Ga of the scale of Harikambodi Mela. Sa Ri Ga Ma Pa Da ni Sa. Hard blowing induces the octaves of the svaras. For reference to the flatter or sharper notes, books on the playing of the flute may be referred to,

42.3 Nagaswara : This is an air-blown instrument. It has a conical bore like the Oboe as contrasted with cylindrical bore of the clarionet. As used in South India it is an open air instrument for temple music, and classical music can be played on it with all its graces. It has no stops nor keys. It has eight holes for the fingers to play on, like the flute, and is set to the Harikambodi mela. There are four side holes lower down, apparently to keep up the tone. The higher svaras are obtained by hard blowing through the reed placed inside the mouth and pressed by the lips. In the case of nagasvara, the hard blowing produces only the octave like the flute.

(C. S. 22nd July 1959)

APPENDIX - I

DIAGRAM OF TUNING THE PIANO

	Sa Ri Ga	ma	da ni
Ma Pa	Da	Ni	ri ga
	Pa Sa Ga	Pa Ni Ri-Ri ma Da	ri ma da
	Ma Da Sa	Pa Ma	
			Check- with ga & old Ma

Check with major chords - at each stage as far as possible and to be as smooth as possible. | (Sa Ma ni ga)

C. c' & c'' tuning forks available. The process is really from Ma to Ma.

Ma] Sa Pa Ri Da Ga Ni ma ri da ga ni
Passage from one note to the next in tuning.

APPENDIX - II

In the appendices following, we are giving a few extracts, from a few Indian authors who had had a glimpse of the Western Science of Acoustics, and their exuberations of what frequencies can be assigned to the ancient 22 srutis in the Indian gamut. It would appear that they would stick and maintain the sanctity to the number 22 and hence all their explanations. Clements, however, wanted two more srutis.

The sloka of the 22 'srutis' in the Octave probably meaning intervals is from the time of Bharata probably 6th century A. D. and

repeated ad nauseam by Sharangadeva (middle of 13th century) and later writers upto Tulaja of Tanjore 1788 is as below :

Chatuh Chatuh Chatuh Chaiva, Shadja Madhyama Panchamā Dve Dve Nishada Gāndhārau, Tri Tri Rishabha Dhaivatau meaning: Sa, Ma and Pa have 4 srutis each. Nishāda and Gāndhāra have 2 srutis each; Rishabha and Dhaivata have 3 srutis each; making the Dva Vimsati (22) srutis. In this connection, Sri V. N. Bhatkhande in his book 'A Comparative Study of Some of the Leading Music Systems of the 16th, 17th and the 18th Centuries' at page 16 explains thus : "According to Bharata then, the sruti was a real unit of measurement in determining the ratio between the several Svaras. In other words, the ratio of the first to the second sruti was equal to the ratio between any two consecutive srutis. There are twenty two srutis in all and if we take the starting point to be the sruti of 'ni' in the lower octave, and as equal to 1, then the twentysecond sruti, that is of the higher 'ni' would be 2. There being twenty-two equal intervals between the higher and the lower 'ni' each interval would be equal to the twenty-second root of 2."

".....The late Pandit Abraham of Tanjore also read a paper (1916) before the first All - Indian Music Conference at Baroda on the srutis of Sharangadeva and showed that no scale in which the srutis were taken as unequal could under any circumstance be accepted as Sharangadeva's shuddha scale."

When Indians began to read modern physics, their effusion in regard to the fixation of the frequencies of the 22 srutis are given in the following appendicies III and IV extracted from 'Gana Bhaskara' a Telugu publication by K. V. Srinivasa Iyengar. It would appear to the author that the past musicologists were more intent on fixing the probable frequency ratios of 22 srutis of the ancient texts, without reference to the *present day* music, which should have been studied on a scientific basis and Prof. Vissa Apparao's (of the Presidency College) foreword to the Grammar of Music (I Edition) would bear out the above statement.

APPENDIX - III

(Extracted from Gana Bhaskara)

1. C. Nagoji Rao.			2. Mr. K. B. Deval.			
Srutii No.	Svara Names	R. F.	Sruti No.	Svara	Vibrating length	Cyclic cents
1	Sa	1				
2	R 1	25/24	1	Sa	1	
3	R 2	16/15	2	R 1	20/21	84
4	R 3	10/9	3	R 2	15/16	112
5	R 4	9/8	4	R 3	9/10	182
6	G 1	32/27	5	G 1	8/9	204
7	G 2	6/5	6	G 2	27/32	294
8	G 3	5/4	7	M 1	5/6	316
9	G 4	32/25	8	M 2	4/5	386
10	M 1	4/3	9	M 3	64/81	408
11	M 2	27/20	10	M 4	16/21	471
12	M 3	45/32	11	P 1	3/4	498
13	M 4	36/25	12	P 2	32/45	590
14	Pa	3/2	13	P 3	45/64	610
15	D 1	25/16	14	P 4	2/3	702
16	D 2	8/5	15	D 1	40/63	786
17	D 3	5/3	16	D 2	5/8	814
18	D 4	27/16	17	D 3	3/5	884
19	N 1	16/9	18	N 1	16/27	906
20	N 2	9/5	19	N 2	9/16	996
21	N 3	15/8	20	S 1	5/9	1018
22	N 4	48/25	21	S 2	8/15	1088
23	Sa	2	22	S 3	128/243	1110
			23	S 4	1/2	1200

1. Wrote the preface for Subbarama Dikshitar's magnum opus (1904) and was the author of The Method of Learning and Teaching Music in Tamil (1901).

2. Mr. Deval studied Somanath's (a South Indian) 'Raga Vibodha' and its commentary and wrote out charts of the srutis in Royal Asiatic Society's Journal.

APPENDIX - IV

(Extracted from Gana Bhaskara)

3. MR. E. CLEMENTS,

4 Raja Sourindro Mohun Tagore

Sruti No.	Svara	Vibrating length	Cyclic cents	From Ellis-Page 517 H. Additions-Appendix 20 Section K)			
Sa	1					Cyclic Cents	
				Degrees	Notes	Old	New
1	R 1	20/21	84	1	C	0	0
2	R 2	15/16	112	2	D_{bb}	51	49
3	R 3	9/10	182	3	D_b	102	99
4	R 4	8/9	203	4	...	153	151
5	G 1	27/32	294	5	D	204	204
6	G 2	5/6	316	6	E_{bb}	264	259
7	G 3	4/5	386	7	E_b	325⅓	316
8	G 4	64/81	408	8	E	386	374
9	M 1	16/21	471	9	E §	442	435
10	M 2	3/4	498	10	F	498	498
11	M 3	20/27	520	11	..	549	543
12	M 4	32/45	590	12	F §	600	589
13	M 5	45/64	610	13	F §§	651	637
14	Pa	2/3	702	14	G	702	685
15	D 1	40/63	786	15	A_{bb}	753	736
16	D 2	5/8	814	16	A_b	804	787
17	D 3	3/5	884	17	...	855	841
18	D 4	16/27	906	18	A	906	896
19	N 1	4/7	969	19	B_{bb}	966⅔	952
20	N 2	9/16	996	20	B_b	1027⅓	1011
21	N 3	5/9	1018	21	B	1088	1070
22	N 4	8/15	1088	22	B §	1144	1135**
23	N 5	135/256	1108				
24	Sa	1/2	1200				

** Extracted also in the Gana Baskara ; the observation therein is that except Shadja others seem to be wrong.

3. Mr. E. Clements was a student of Hindustani Music as well as of South India. He is the author of the book 'Ragas of Tanjore,' (London 1920).

   The author of Gana Baskara observes that Mr. Clements has detected 2 new srutis items 11 and 19 respectively R. Fs 27/20 *and* 7/4 in Hindustani music ! His investigations were carried out by a harmonium (a reed instrument.)

4. He reprinted in the book 'Hindu music' from various authors! Sir Williams Jones's tract with many others where reference has been made to the words Graha, Nyasa and Amsa etc. *vide* foot-note at page 243 (Ibid) H.

APPENDIX – V

Extracts from 'Hindusthani Music, an Outline of its Physics and Aesthetics' by G. H. Ranade, B. Sc.

Mr. Ranade has calculated the number of srutis in each of the important musical intervals by finding the value of r in the equations like $3/2 = 2^{r/22}$. C. S.

Interval.			Mathematically derived value of (the No. of srutis in the interval)	Values assigned by the ancient Indian writers.	
Octave	...	2	22	22	
Fifth	...	3/2	12.86	13	
Fourth	...	4/3	9.14	9	
Major Third	...	5/4	7.08	7	
Minor Third	...	6/5	5.78	6	
Major Tone	...	9/8	3.72	4	
Minor Tone	...	10/9	3.36	3	„
Just semi Tone	...	16/15	2.06	2	
To complete the Tables					
		C. S.			
Minor sixth	...	8/5	14.917	15	
Major sixth	...	5/3	16.213	16	
Minor Third from Pa		9/5	18.656	19	
Major Third from Pa		15/8	19.952	20	

He thinks therefore that the Indian was not far wrong in these ideas. The explanation offered is certainly plausible for the true notes. (what about others ?). C. S.

Extracts from Mr. G. H Ranade's article 'Eternal Paradox in Indian Music - The Shrutis.' From the booklet 'Aspects of Indian Music.' The Publications Division, October, 1957.

Referring to Mr. Fletcher's workVide Page 85 of 'Wood's Physics' he concludes 'This piece of scientific research lends additional support to my statement that in GAMAKA the SHRUTI intervals do undergo changes, though they be small and for the time being and this is how SHRUTIS are all equal in their acoustic bearing and are yet not the same everywhere in practical music.'

The problem is not, however, solved whether the frequencies, as 22nd roots of 2, besides the 12 notes given by him, are present in Indian music and further as to the extent of the vibrational movements in the gamakas, which he refers to.

Mr. Ranade's arguments regarding how loudness interferes with the estimation of the pitch of a note by the human ear, though it is from a scientific work, we are unable to accept, for the reason that Fox Strangways had stated that ' the European has forgotten pure intonation for three centuries,' that is to say natural notes which the classically trained South Indian ear responds to. When the range of Indian melodic music is barely 2 to $2\frac{1}{2}$ octaves, the ear cannot make a mistake of the pitch of the note owing to its loudness, which may apply perhaps when 7 octaves of the piano are concerned.

Any way, the conditions of those experiments referred to by Mr. Ranade are not exactly identical to what is obtained with the Karnatic music rendered to the background of a drone and therefore these experiments will need to be carried on to a further stage before their results can be fully taken into account.

In pages 91–93 of the 2nd Edition (of 1951) Mr. Ranade has mentioned R.F.'s 7/6 and 7/4 but has not referred to the ragas of Hindustani music where they occur.

APPENDIX - VI

* Extracts from Prof. P. Sambamoorthy's book 'South Indian Music' Book V

New words coined are Purna sruti 256/243, Nyuna Sruti 25/24

Observation 1 : R.F. 256/243 is 90 cyclic cents interval or Pythagorean Limma, the difference of a true fourth from two diatonic seconds, (that is 4/3 divided by 9/8 x 9/8). To use the word Purna, meaning whole, for a complex fraction looks odd. C. S.

Observation 2 : The word Nyuna means lame. R.F. 25/24 is the small semitone, as defined by J. Ellis. Vide Page 453 Helmholtz (ibid). C. S.

We have already referred to Helmholtz's observation regarding three of the notes in the cycle of fifths and three of the notes in the cycle of fourths as not consonant notes with the drone. The only notes with a twentytwo cent interval, R. F's 10/9 and 9/8, which are prolongable, are consonant with the drone of the Tambura.

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